

Journal of Rehabilitation Research and Development

Rehabilitation R & D Progress Reports 1990

VII. Independent Living Aids

A. General

There are multiple methods for access the information in this section of the Progress Reports. You can click on the bookmark in the left panel to go directly to the subject matter, click on the text within the box or scroll down.

B. Robotics

C. Communication Methods and Systems

D. Private and Public Programs

VII. Independent Living Aids

For additional information on topics related to this category see the following Progress Reports: [10], [171], [175], [429], [430], [456], [459], [466], [491], [506].

A. General

[221] Access and Mobility Requirements for Children and Adolescents

Barry R. Seeger, PhD; John H. Bails, BE

Rehabilitation Engineering Division, Regency Park Centre for Young Disabled, Kilkenny, SA 5009 Australia

Sponsor: Channel 7 Children's Medical Research Foundation of S. Australia, Inc.

Purpose—This research was undertaken because of difficulties experienced in designing school buildings to be accessed by children and adolescents with physical disabilities. No previous research had produced design data for access to buildings by young people with disabilities. The hypothesis of the study was that the physical access needs of disabled young people are not the same as those of disabled adults or able-bodied young people, and the extent of their requirements could be defined.

Methodology—The young people included in the study were 288 children and adolescents aged 3 to 18 years, including 179 with physical disabilities. Each subject was tested at 30 test stations, where 72 variables were measured relating to mobility, reach, strength, and size.

Results—Our findings show that, as expected, the physical capabilities of disabled young people aged 3 to 18 years are significantly less than the capabilities of disabled adults and able-bodied young people of the same age. Design data obtained are the results achieved by the

most able 80% of subjects in each age and disability group. A range of detailed guidelines was obtained which now enable building designers to take into account the needs of young people with physical disabilities.

Implications—The significance of this research is that a body of empirical data now exists for determining the design requirements for access to buildings for young people with physical disabilities. It is proposed that standards be developed which lead to improved access to the built environment for these people. The Standards Association of Australia is incorporating these research results in the draft of Australian Standard "Design for Access and Mobility, Part 3: Requirements for Children and Adolescents."

Recent Publications Resulting from This Research

Ergonomic Design for Physically Disabled Children, Parts 1 & 2.
Bails JH, Seeger BR. Kilkenny, Australia: Regency Park Centre, 1990.

Ergonomic Building Design for Physically Disabled Young People.
Seeger BR, Bails JH, Assist Technol (in press).

[222] Development of an Infant Crib to be Used by Physically Disabled Parents

Micheal D. O'Riain, PhD, PEng; Andrew Phillips, BAsC; Louis Goudreau, BAsC, PEng; Gilbert Layeux, Reg Tech; Harold Gay, Reg Tech

Department of Rehabilitation Engineering, The Rehabilitation Centre, Ottawa, Ontario K1H 8M2 Canada

Sponsor: Royal Ottawa Health Care Group

Purpose—The objective of this project is to develop a crib that is easily accessible by a wheelchair-bound or otherwise physically disabled parent. Our specific goals are: 1) to make a crib that is easily accessible to a parent in a wheelchair; 2) redesign the main opening on the crib so that it is easy for wheelchair-bound persons to put the infant into the crib, and take the infant out; and, 3) ensure that all government regulations for cribs are fully met, and that the crib is perfectly safe for both infant and user.

Progress—A prototype crib is being tried out by three families with infants where one of the parents is physically disabled. The disabled parents find it invaluable, and we are proceeding with our efforts to have the crib marketed. In the meantime, we are introducing design changes which should broaden the market for the crib to include able-bodied users.

[223] Development of Systems to Enable Physically Disabled Persons to Board Inter-City Buses

Micheal D. O'Riain, PhD, PEng; Louis Goudreau, BAsC, PEng; Ray Cheng, MHSc, PEng; Andrew Phillips, BAsC; Gilbert Layeux, Reg Tech; Harold Gay, Reg Tech

Department of Rehabilitation Engineering, The Rehabilitation Centre, Ottawa, Ontario K1H 8M2 Canada

Sponsor: Transportation Development Centre, Transport Canada

Purpose—The purpose of this project was to design systems which would enable disabled persons to board (and therefore travel on) inter-city buses.

Progress—Two methods to enable physically disabled persons board inter-city buses have been developed. Full-scale operational mock-ups have been built of both systems. Tests on the mock-ups have shown that production versions of either system could be used to bring disabled persons into buses. A fully portable boarding system which could be carried in the luggage compartment of the bus would be a useful addition to the systems already designed and developed by us. The bus-boarding contract was awarded by Transport Canada in 1988, and has been successfully completed. A final report has been published by Transport Canada.

Results—We refined several parameters of the bus-boarding process: 1) boarding is best achieved by having the disabled client transfer to a special boarding chair prior to being brought into the bus. This transfer can be done at any convenient location in the bus terminal; 2) a boarding system should bring the special chair (with its

occupant) into the bus and place it beside the first row of seats: a level transfer can then be made if the armrest of the first row of seats can be pivoted upwards; and, 3) due to the confined space at the entrance to a bus, as well as the bus aisle, a boarding system must be designed that does not take up space which would otherwise be occupied by the client during boarding.

The two systems tested by us are designed to be based at a bus station. One of the systems uses an electrically-powered stair-lift to bring the transfer chair (with the client) into the bus. In addition to needing electric power, two operators are required for this process. The second system uses a manual ramp to bring the transfer chair into the bus. This is a relatively bulky system, but only one operator is required and no electric power is used.

While our two bus-boarding systems will work very well in the stations in which they are installed, neither boarding nor deboarding can be done in bus stations not equipped with these systems, nor in emergency situations away from a bus terminal. For this reason, we are advocating that a third and fully portable system be developed. Such a system, which was described in conceptual form

in a report for Transport Canada in 1987, could be stored in the luggage compartment of the bus and could be deployed by a single operator when needed. Other future developments may include the construction of operational prototypes of our original two systems.

B. Robotics

[224] Clinical Evaluation of a Vocational Desktop Robotic Aid for Severely Physically Disabled Individuals

Inder Perkash, MD; Stefan Michalowski, PhD; Machiel Van der Loos; Joy M. Hammel, MA, OTR; Dean Chang, BS
Rehabilitation Research and Development Center, VA Medical Center, Palo Alto, CA 94304

Sponsor: *VA Rehabilitation Research and Development Service (Project #B239-2RA); Rehabilitation R&D Center Core Funds; VA Spinal Cord Injury Center*

Purpose—There are over 67,500 quadriplegics in the United States today, with an estimated 2,400 to 4,000 new injuries resulting in quadriplegia each year. These injuries occur most frequently to young males, and they can expect to live a relatively normal life span. Of these individuals, less than 12% are employed. Computer technology can provide a measure of independence for disabled individuals and is a fast-growing field of employment for the disabled; however, computers alone fail to address the manipulation needs of individuals who have no use of their arms and legs. In order to address this need for independence in the worksite and to provide a vocational tool for severely physically disabled persons, a vocational desktop robotic assistant (DeVAR-IV) has been developed, and is currently undergoing evaluation at the worksites of disabled individuals employed in the computer field.

Progress—In August 1989 we installed a DeVAR system in the office of a programmer in a local company. He has used the robot on a daily basis for four 10-hour days per week. Under voice control, DeVAR has been programmed to complete 10 tasks, including feeding lunch and medication, handling routine telephone dialing and answering, sorting office papers, arranging printer output on a copystand, handling fanfold computer print-outs, handing the person a mouthstick, and offering him a drink.

Results—A 2-week study to compare performance between an attendant and a robot completing the same desktop tasks was completed in the summer of 1989. Data

Recent Publications Resulting from This Research

Evaluation of Two Station-Based Boarding Systems for Inter-City Buses. O'Riain MD. Montreal: Transportation Development Centre, Transport Canada (in press).

analysis is ongoing and will be reported in the coming year. Preliminary results indicate that there is a difference in completion times between the attendant and the robot for the desktop tasks, but that this has minimal effect on job productivity given the nature of the tasks and robot usage.

Implications—In conclusion, although a robot entails a significant capital investment for the employer or employee, the maintenance costs are minimal compared to the continuing costs of hiring an attendant for 40 hours per week and of retraining new attendants (on the average, three to five new attendants hired per year). A \$50,000 to \$100,000 system can be expected to pay for itself in about 3 years. The process of transferring the technology to the private sector has been started and is expected to lead to timely product introduction.

Recent Publications Resulting from This Research

Clinical Evaluation of a Desktop Robotic Assistant. Hammel JM et al., *J Rehabil Res Dev* 26(3):1-16, 1989.

Design and Evaluation of a Vocational Desktop Robot. Van der Loos HFM et al., in *Proceedings of the 12th Annual RESNA Conference*, New Orleans, 107-108, 1989.

Designing Rehabilitation Robots as Household and Office Equipment. Van der Loos HFM, Hammel JM, in *Proceedings of the International Conference on Rehabilitation Robotics, A.I. DuPont Rehabilitation Research Institute*, Wilmington, DE, 1990.

Field Evaluation of a Robot Workstation for Quadriplegic Office Workers. Van der Loos HFM et al., *CARDIOSTIM 90 Conference*, Nice, France, 1990.

A Voice-Controlled Robot System as a Quadriplegic Programmer's Assistant. Van der Loos HFM et al., in *Proceedings of the 13th Annual RESNA Conference*, Washington, DC, 129-130, 1990.

[225] High Speed Obstacle Avoidance (Mobile Autonomous Robot Base for Rehabilitation Applications): A Pilot Study

Simon P. Levine, PhD; Johann Borenstein, DSc; Lincoln A. Jaros, BS; Ulrich Raschke, MS; Yoram Koren, DSc
VA Medical Center, Ann Arbor, MI 48105; University of Michigan, Rehabilitation Engineering Program,
Mobile Robot Laboratory, Ann Arbor, MI 48109-0032

Sponsor: VA Rehabilitation Research and Development Service (Project #B989-PA)

Purpose—The purpose of this pilot study is to implement a high speed obstacle avoidance system on a Denning DRV-1W Robot. This system will allow the robot to travel at normal walking speeds and automatically steer around obstacles in its path, with little or no slowing. The basic technique employed was developed within the scope of an independent research project focusing on mobile robot applications in hazardous environments. This pilot study will implement the obstacle avoidance algorithms on the Denning robot in a form which can be integrated with companion tracking and global travel subsystems.

Methodology—The Denning robot has a built-in ring of 24 ultrasonic sensors which supply the raw detection data used by the software. By sampling distance data from these sensors at a rapid rate, the obstacle avoidance software can build and continuously update a real-time map of the environment, including both stationary and moving objects. The heart of the system is the “Virtual Field Histogram” algorithm, which uses the information within the map to plan platform movements in real time, allowing the robot to reach a desired final location while avoiding collisions along the way.

Results—During the last year, the on-board 68000 computer has been replaced with a 20 MHz 80386. This allows existing obstacle avoidance software (written in the C programming language) to be ported from another research robot to the Denning platform used in this pilot study. The ring of ultrasonic transducers present in the Denning has been interfaced to the main 80386 over a high-speed serial link. Initially, this serial link and others already present in the Denning were a source of frequent internal communication problems. These problems have been corrected by switching from RS-232 to RS-422 serial communication.

The obstacle avoidance software has been ported to the Denning robot. Modifications necessary to operate

this software with Denning hardware are largely completed, and testing and optimization of the algorithm has recently begun. Several safety features have been added to prepare the platform for increased autonomy during testing. These include a remote-operated kill switch and a built-in watchdog timer circuit.

Future Plans—The obstacle avoidance algorithm being used in this project was initially developed using a Cybermation K2A mobile robot combined with a custom-designed ultrasonic ranging system. This custom sonar system was designed to provide several specialized functions not presently available with the commercial Denning ultrasonic system. To allow the Denning to take full advantage of the sonar mapping algorithms, it will be necessary to add these features to the Denning sonar system. This will be accomplished by altering the device driver software supplied by Denning with the platform. Once this is accomplished, future work will include the integration of the obstacle avoidance subsystem with the companion tracking and global travel systems described in accompanying reports.

Recent Publications Resulting from This Research

- Mobile Robot System for Rehabilitation Applications. Levine SP et al., in Proceedings of the 12th Annual RESNA Conference, New Orleans, 185-186, 1989.
- Semi-Autonomous Mobile Robot Platform for Rehabilitation Applications. Levine SP et al., in Proceedings of the International Advance Robotics Programme First Workshop on Domestic Robots and Second Workshop on Medical and Healthcare Robotics, United Kingdom Department of Trade and Industry, 15-18, 1989.
- Fail-Safe Features of a Mobile Robotic Platform. Jaros LA et al., in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 291-292, 1990.
- Ultrasonic Sensor System for Mobile Robot Obstacle Avoidance and Navigation. Borenstein J, Levine SP, Koren Y in Proceedings of the 1990 International Conference on Rehabilitation Robotics, A.I. DuPont Institute, 121-131, 1990.

[226] Global Travel (Mobile Autonomous Robot Base for Rehabilitation Applications): A Pilot Study

Simon P. Levine, PhD; Johann Borenstein, DSc; Yilin Zhao, MS; Ulrich Raschke, MS; Lincoln A. Jaros, BS; Spencer L. BeMent, PhD

VA Medical Center, Ann Arbor, MI 48105; University of Michigan, Rehabilitation Engineering Program, Mobile Robot Laboratory, Ann Arbor, MI 48109-0032

Sponsor: VA Rehabilitation Research and Development Service (Project #B990-PA)

Purpose—A mobile robot must be able to plan a path in order to travel from one point in an environment to another. However, even in fairly well-structured environments, unexpected objects can obstruct a robot's pre-planned path. In such cases, in addition to employing local obstacle avoidance capabilities to circumnavigate unexpected objects, the robot may need to plan an alternative path to the required destination.

This pilot study entails the implementation of a global travel system designed to work in conjunction with an obstacle avoidance system. The system includes a path planner as well as an infrared (IR) beacon system for determining absolute position. These systems are intended to allow a mobile robot to store information about the environment in a "world model," and then compute (or recompute) optimal paths in order to navigate within dynamic environments.

Methodology—The global path-planning algorithm being developed is an enhancement of the A* algorithm and is being integrated with the previously developed local obstacle avoidance algorithm already present on this robot. The integration allows for the mutual use of the world model information so that information gathered by the local obstacle avoidance system is made available to the global path planner whenever it is invoked. In this way, a path to the desired target location can be planned which takes into account all the known information as well as any unexpected obstacle information that may have been observed by the robot in its travels.

The absolute positioning system uses a commercially available IR beacon system from Denning, which consists of a rotating IR detector mounted on the robot and coded beacons which are fixed at known locations throughout the environment. By spotting three of these from one location, the absolute position of the robot can be triangulated.

Results—A new triangulation algorithm has been developed which allows for greater flexibility in the placement of the beacons and automatically finds the precession as well as the position of the robot. Our research has also

shown that the current beam width of the Denning beacons (approximately 10 degrees) is too narrow; they are being modified in order to increase the area from which they can be seen. Additionally, improvements in absolute positioning are being further investigated in terms of using the correlation of sensor information with information stored in the world map (such as the location of walls). As part of this research, a method to determine the relative quality of the maps created by the sonar data has been developed.

Future Plans/Implications—We plan to completely integrate the absolute positioning, global path-planning, and local obstacle avoidance systems on the Denning DRV-1W robot as part of this 1-year pilot project. This will include the ability to detect "trap" or other unexpected conditions (such as a closed door) in the local obstacle avoidance mode and automatically invoke the global path planner when required. Similarly, the local obstacle avoidance mode will automatically deviate from the suggested global path if unforeseen obstructions are encountered.

In parallel with this integration, we plan on further enhancing the global path-planning algorithm to take into account very large environments. This will require the development of high-speed map simplification (data reduction) routines for efficient memory storage and recall.

Recent Publications Resulting from This Research

Dynamic Path Planning for Mobile Robot Real-Time Navigation.

Zhao Y, BeMent SL, Borenstein J, in Proceedings of IASTED International Symposium Robotics and Manufacturing, 162-166, 1989.

Mobile Robot System for Rehabilitation Applications. Levine SP et al., in Proceedings of the 12th Annual RESNA Conference, New Orleans, 185-186, 1989.

Semi-Autonomous Mobile Robot Platform for Rehabilitation Applications. Levine SP et al., in Proceedings of the International Advance Robotics Programme First Workshop on Domestic Robots and Second Workshop on Medical and Healthcare Robotics, United Kingdom Department of Trade and Industry, 15-18, 1989.

A Comparison of Grid-Type Map-building Techniques by Index of Performance. Raschke U, Borenstein J, in Proceedings of the IEEE International Conference on Robotics and Automation, 1828-1832, 1990.

[227] Companion Tracking (Mobile Autonomous Robot Base for Rehabilitation Applications): A Pilot Study

Simon P. Levine, PhD; Johann Borenstein, DSc; Lincoln A. Jaros, BS; Ulrich Raschke, MS; Yoram Koren, DSc
VA Medical Center, Ann Arbor, MI 48105; University of Michigan, Rehabilitation Engineering Program,
Mobile Robot Laboratory, Ann Arbor, MI 48109-0032

Sponsor: VA Rehabilitation Research and Development Service (Project #B99I-PA)

Purpose—The purpose of this pilot study is to design, develop, and implement a nonphysical link between a robot (Denning DRV-1W mobile robot) and a user-companion. This system will allow the robot to autonomously follow or guide the user. It will integrate sensor information from several subsystems and generate robot movement commands to cause the mobile platform to follow the companion automatically. The goal of the pilot study tracking system is to reliably follow a companion in the laboratory setting, maintaining a follow distance of 0.5 to 2.0 m, even with other individuals crossing between the robot and companion.

Methodology—The tracking system under development depends on two sensor systems. The first is based on an infrared (IR) detector capable of measuring the direction to a coded IR beacon. The detector is mounted on the mobile platform and can accurately calculate the direction to individual beacons. With one or more beacons placed on the robot's companion (e.g., on a belt), the robot can use the IR detector to uniquely identify the direction of the companion from among all objects present in the operating environment.

The second sensor system involved in tracking is a ring of 24 ultrasonic sensors mounted in a ring around the platform. This ring measures the distance from the robot to the nearest obstacle in each of the 24 circular directions. This information is primarily used by the obstacle avoidance system to control robot motion. However, it will also be used to measure the distance between the robot and its companion.

Results—The two sensor systems are now operational. The ultrasonic detector ring is working properly to supply

distance information for both obstacle avoidance and for companion tracking. The IR detection system is able to identify direction and calculate absolute position within the environment. However, the beacons supplied with the IR system are too large and too directional to be effectively worn by the companion. Therefore, the beacon is being redesigned so that it can be mounted unobtrusively on a piece of clothing and will be able to disperse its beam through a much wider angle.

Future Plans—The main task remaining for this 1-year pilot study is to integrate the raw data coming from ultrasonic and IR detectors into a coherent picture of the relative locations of the robot and companion. The companion tracking system has been designed so that data from both of these sensors are integrated into the same map used for obstacle avoidance and global travel. From this map the robot will need to calculate and execute the movement commands necessary to allow the mobile platform to follow the companion. Movement commands will be edited by the obstacle avoidance software which is already running on the platform.

Recent Publications Resulting from This Research

Mobile Robot System for Rehabilitation Applications. Levine SP et al., in Proceedings of the 12th Annual RESNA Conference, New Orleans, 185-186, 1989.

Semi-Autonomous Mobile Robot Platform for Rehabilitation Applications. Levine SP et al., in Proceedings of the International Advance Robotics Programme First Workshop on Domestic Robots and Second Workshop on Medical and Healthcare Robotics, United Kingdom Department of Trade and Industry, 15-18, 1989.

Ultrasonic Sensor System for Mobile Robot Obstacle Avoidance and Navigation. Borenstein J, Levine SP, Koren Y in Proceedings of the 1990 International Conference on Rehabilitation Robotics, A.I. DuPont Institute, 121-131, 1990.

[228] Rehabilitation Robotics Research at King's College, London

John L. Dallaway; Andrew J. Tollyfield

Department of Electronic and Electrical Engineering, King's College, London WC2R 2LS UK

Sponsor: *None listed*

Purpose/Methodology—Research within the Information Engineering Research Group at King's College, London has been directed at the development of a Telethesis Control System known as TASK FORCE. This software drives an RTX robot arm in a workstation environment and runs on any PC-compatible computer using a single switch input. The emphasis of the research lies in the provision of a low-cost aid requiring minimal operating skill for high-level quadriplegics. Robotic aids have traditionally been controlled in a motion-specific manner by directing the position of the end-effector within a particular coordinate frame. In order to reduce the cognitive demands on the user, TASK FORCE provides task-specific control of the telethesis. Single-object transfers of the form "Move Object A onto Shelf B" are combined with more manipulative functions to perform complex tasks. This system provides greater flexibility than preprogrammed systems and requires no trajectory training phase. Task Planning is achieved using efficient collision avoidance algorithms which interrogate a simple environmental model.

Progress/Results—Over the past year, TASK FORCE has been refined through an iterative series of user trials and procedural modifications. Evaluation of the system has taken place at both a residential center for adults and a school for teenage children. Most recently, volunteers have been asked to complete a coffee-making task using

a water dispenser and a miniature water boiler. Many users expressed doubt as to their ability to carry out such a task, but all achieved some degree of success.

The teenage children involved in the trials were able to adapt to the new technology more rapidly than the adults. Many of the younger users had gained considerable experience with word processing software at the school and therefore adapted to the hierarchical menus presented on the computer monitor with ease. Mistakes in the use of the control system were generally caused by a lack of concentration rather than a misunderstanding of the user interface.

The trials have demonstrated the way in which motion-specific and task-specific control concepts may be integrated under a common user interface in such a way as to obscure the inherent differences between the two approaches. Users appeared to be unaware that they had switched between the various modes of operation because their concentration was on the task itself.

Recent Publications Resulting from This Research

Task Specific Telethesis Control. Dallaway JL, in Proceedings of the IARP 2nd Workshop on Medical & Healthcare Robotics, 285-298, 1989.

Task Planning Strategies for the RTX Robot Arm. Dallaway JL, in Proceedings of the International Conference on Rehabilitation Robotics, 1990.

Task Specific Control of a Robotic Aid for Disabled People. Dallaway JL, Tollyfield AJ, J Microcomput Appl (accepted for publication).

[229] Human-Machine Interaction via the Transfer of Power and Information Signals

H. Kazerooni

Department of Mechanical Engineering, University of Minnesota, Minneapolis, MN 55455

Sponsor: *National Science Foundation*

Purpose—Robot manipulators perform tasks which otherwise would be performed by humans. However, robot manipulators often fail to achieve performance comparable to human performance. For example, humans excel at avoiding obstacles, assembling complex parts, and picking up fragile objects. In physical (mechanical) strength, robots can outperform humans. If robot mechanical

strength could be integrated with human physical strength under the control of the human intellect, we would have an intelligent, strong, maneuvering device for a variety of tasks.

Extenders are devices worn by humans which increase human mechanical ability, while the human intellect serves as the central intelligent control system

for manipulating the extender. Commands are transferred to the extender via the contact forces between the human and the extender, eliminating the need for a joystick, push-button, or keyboard to transfer such commands. The operator becomes an integral part of the extender while executing the task. When the human uses the extender to touch and manipulate an object, the extender transfers to the human arm, as natural feedback, a scaled-down value of the actual external load which the extender is manipulating: the human "feels" the external forces in the manipulations. Thus, extenders can be used to maneuver heavy loads with greater dexterity, speed, and precision. In many situations, extenders can replace fork-lifts.

Workers frequently maneuver objects manually without the assistance of any lifting devices. When a worker maneuvers an object with the assistance of an extender, the worker endures smaller forces, and consequently suffers fewer work-related injuries.

Considering these advantages, two large markets for the extender technology can be identified: 1) work situations in which objects weighing less than 400 lbs must be lifted in spaces where fork-lifts and similar devices cannot operate; and, 2) work situations in which objects weighing less than 50 lbs (e.g., baggage) are lifted by workers manually without the help of any lifting devices: although workers can lift such objects manually, the frequent repetitive maneuvering of such objects often causes injuries.

Progress—To develop and test nonlinear control algorithms, a direct-drive, electronically-powered extender was built. The direct connection of the motors to the links (without any transmission systems) produces highly nonlinear behavior in the extender. This extender has two degrees-of-freedom corresponding to a shoulder and an elbow. Two motors are located at the same height as the average human shoulder. Force sensors are located at the

human-extender and extender-load interfaces. A third degree-of-freedom may be added: either rotation about a vertical axis or roll about a horizontal fore-aft axis.

Accomplishments include: 1) nonlinear stability analysis and the trade-offs between stability and performance for extenders with nonlinear behavior; 2) the nonlinear control algorithm that creates force amplification over amplification over a wide frequency range; 3) a set of experimentally-verified mathematical ground rules for controllers of general robotics worn by humans (e.g., orthoses for disabled people); 4) the feasibility of using electric actuators for high-speed maneuvers of small loads (i.e., less than 50 lb); 5) the trade-offs between stability and performance (i.e., force implication); 6) the role of human dynamics in the control of the extender system; 7) a stable control algorithm which creates robustness in the presence of human impedance variations; and, 8) a stable adaptive control algorithm which creates uniform performance in the presence of load variations.

Recent Publications Resulting from This Research

- On the Stability of the Human/Machine Interaction. Kazerooni H et al., NASA Conference on Space Telerobotics, Pasadena, CA, 1989.
- On the Stability of Robotic Systems Worn by Humans. Kazerooni H, Foslien WK, American Control Conference, Pittsburgh, 1989.
- On the Trade-offs Between Stability and Performance in Human-Machine Interaction. Kazerooni H, IEEE Conference on Systems, Man and Cybernetics, Boston, 1989.
- Force Augmentation in Human-Robot Interaction. Kazerooni H, Mahoney SL, American Control Conference, San Diego, 1990.
- Human-Robot Interaction via the Transfer of Power and Information Signals. Kazerooni H, IEEE Transactions on Systems and Cybernetics 20(2), 1990.
- Stability and Performance of Robotic Systems Worn by Humans. Kazerooni H, IEEE International Conference on Robotics and Automation, Cincinnati, 1990.

Awards

- The O. Hugo Schuck 1989 Best Paper Award, American Control Conference. Awarded in May 1990.

[230] Development of Semiautonomous Control for the UT/HMRC Robotic Aid

Cheryl Masanic, MASc; Morris Milner, PhD, PEng, CCE; Andrew Avi Goldenberg, PhD
 Hugh MacMillan Rehabilitation Centre, Toronto M4G 1R8 Ontario Canada; Department of Mechanical Engineering, University of Toronto, Toronto M5S 1A1 Ontario Canada

Sponsor: *Natural Sciences and Engineering Research Council of Canada; Canadian Paraplegic Association*

Purpose—The purpose of this project is to develop a semiautonomous control system within a general purpose

robotic aid for high-level quadriplegics. This system will offer the flexibility of adapting the robotic aid to an

unstructured environment, while avoiding a heavy control burden on the user.

The first specific goal is to implement a semi-autonomous control strategy in software with the following control attributes: 1) instructability—to allow the definition of new objects and locations within the workspace, and to allow user-defined tasks; 2) repeatability—to allow repetition of user-defined tasks; 3) adaptability—to allow the system to adapt to a non-rigid environment; and, 4) modularity—to allow the replacement of variables that constitute a learned task in order to perform a functionally different task, but of similar primitive behavior.

The second specific goal is to compare the functional benefit of the semiautonomous control strategy with more traditional control strategies.

In the domain of technical aids for the handicapped, much research has been directed at transferring robotics technology to physically disabled persons with the goal of providing them with autonomy. With the advances made in robotics and computer technology, it is now possible to allow a high-level quadriplegic to partially manipulate the environment with limited external assistance. Our present efforts are directed at developing a semiautonomous system which incorporates the flexibility of direct control and the ease of use of a workstation into a single system.

Methodology—Primitive Commands: A set of primitive commands that address the needs of this population will be defined. Needs will be determined through a review of the literature. Tasks will be categorized and delineated to obtain the essential primitives to perform a set of desired tasks.

Implementation: In order to attain the control attributes, the following software components will be addressed: trajectory generation, environmental attributes, data structures, and user interface. The system will be implemented on a UMI RTX manipulator, controlled by an IBM PC/AT-compatible computer. A VOTAN speech recognition unit will be provided for user input. Three infrared proximity sensors, mounted on the robot's gripper, provide the feedback required by the automatic grasping algorithm.

Clinical Testing: Testing will consist of asking the user to perform specified tasks after training. The tasks will be designed to take full advantage of the semiautonomous control system. The user will also perform these tasks using the more traditional direct control approach. A questionnaire will be administered after each test. This

questionnaire will be designed to measure users' attitudes and opinions toward the control strategies.

Results—A preliminary set of primitive commands has been developed. These commands comprise three categories: 1) variable-dependent (e.g., GO TO location, GET object, MOVE object TO location, where "object" and "location" are variables which can be defined by the user); 2) direct control (e.g., forward, elbow left, down); and, 3) time-dependent (e.g., WAIT).

The four control attributes were achieved by allowing the system to operate in two modes: "LEARN" and "REPEAT."

Instructability and *Repeatability* are implemented by allowing the user to guide the manipulator through a desired task using the primitive commands available. Once completed, the entire sequence of steps and all variables that constitute the task are saved in memory under a new task name. This procedure is possible in LEARN mode. When a task has been instructed and saved, the user switches to REPEAT mode. In this mode, all tasks previously defined under LEARN mode can now be invoked. When an object or location is unknown to the system, the user switches to LEARN mode and guides the manipulator using direct control primitives to teach the necessary parameters.

Adaptability was achieved with an internal model that represents objects and locations. Associations with their names are updated as the environment is altered.

Modularity can be illustrated with the following simple example: in LEARN mode, the user has defined the task DRINK as:

MOVE milk TO mouth

WAIT

MOVE milk TO counter

In REPEAT mode, the user reissues DRINK.

The system responds by showing the sequence of primitives that constitute DRINK and the variables previously associated with it (milk, mouth, counter). At this point the user can either accept the default values or substitute "milk" with "pop," and "counter" with "shelf," as long as these variables have been taught using the appropriate provision. This illustrates the strength of this method in its ability to modularize tasks.

Future Plans/Implications—Formal clinical evaluation of the system will be conducted upon completion of the aforementioned implementation. We anticipate a considerable reduction in the control burden on the user.

[231] Design and Implementation of a Rehabilitation Robotics Programming Environment

Michel L. Gilbert, BA

Applied Science and Engineering Laboratories, Alfred I. duPont Institute and The University of Delaware, Wilmington, DE 19899

Sponsor: Nemours Foundation

Purpose—The Programming Environment Project seeks to address the need for a standardized rehabilitation robotics programming environment. Designed for the professional robotics programmer, this environment would include all of the basic software and hardware tools necessary for minimizing the engineering effort involved in developing a specific clinical or research application. This development falls into three broad development areas. First, the design of a standard software interface to provide communication between the computer and the robotic manipulator. Second, the design of a standard software interface to provide communication between a user and the computer via a variety of input devices. Finally, the selection of, and where necessary, the development of programming utilities useful to a research of applications development environment. This project also serves as the technical support project for the Rehabilitation Robotics Research Program at the Alfred I. duPont Institute.

Progress—The previous year has seen the development of a prototype control library implemented on the RTX robot. The library consists of three levels of access to the robot: motor-space, joint-space, and reference frame-space. Three reference frames have been implemented in open-loop: Task-Oriented, Base, and Tool. Documentation for Version 1.0 of the library is complete.

An objects data structure (C-library) has been created and documented. This library allows for the management of abstract *objects* in space. Documentation is currently in progress. Both the objects library and the robot library use a common data structure to represent position information. Preliminary tests using small, specialized applications and either keyboard, joystick, or powerglove input, indicate that the library will function as predicted and provide a powerful interface and programming environment.

Future Plans—The 1991 project year will include testing and evaluation of the existing software, and expansion of the project into a number of new areas:

Field test developed software. Software developed in the first year and a half of the project will be tested in both internal and external research projects. Internal

projects will include the Hybrid Force/Position, Human Interface, and Analog Control projects. External projects will include Ohio State and Cambridge Universities.

Investigation of closed-loop control. Robot control is currently functioning open-loop. Closed-loop control has the potential for providing more accurate control, but requires implementation of error correction capabilities. The resulting code will need to be evaluated and compared with the open-loop approach for accuracy and stability.

Implementation of the robot library on a second robot. The Manus robot will be available in the early part of 1991 and will be the second robot on which the control model will be implemented. Manus is a wheelchair-mounted system designed specifically for rehabilitation applications. Given the flexibility of its environment, Manus is ideally suited to direct control and will serve as a powerful test of the modularity and effectiveness of the robot control architecture.

Development of an input device architecture. The architecture must be possessed of a number of features. Application code must be able to access the specified input device in a standard way, and must be able to dynamically select from implemented device drivers.

Utility development (graphics and reference). Development of programming utilities will consist of two parts: 1) the project survey will be completed and programming tools extracted from the survey will be assembled in a reference document and disseminated at both the RESNA and ICORR '91 conferences; and, 2) the use of graphics as both a programming tool (i.e., robot simulation), and an interface tool (i.e., feedback and control), will be evaluated and the necessary software tools developed.

Recent Publications Resulting from This Research

Development of a Programming Environment for Rehabilitation Robotics. Gilbert M et al., in Proceedings of the 12th Annual RESNA Conference, New Orleans, 377-378, 1989.

RTX Robot Control Library: Straight Line Motion. Caruso J, Gilbert M, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 329-330, 1990.

A Software Tool for Manipulating Objects in Space. Gray J, Gilbert M, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 121-122, 1990.

[232] Task-Oriented Hybrid Force/Position Control

William Crochetiere, PhD; Richard Mahoney, MS; Tariq Rahman, PhD; Edward Walsky, BS
Applied Science and Engineering Laboratories, Alfred I. duPont Institute and The University of Delaware,
Wilmington, DE 19899

Sponsor: *Nemours Foundation*

Purpose—This project proposes to research and develop strategies for robot compliance using a hybrid of force sensing and position control.

Progress—The RTX manipulator is being used in this project. In the first year, the position aspect of the hybrid control has been investigated. A kinematic and velocity solution of the RTX has been derived. This solution was programmed in the C language and forms the nucleus of the control algorithm.

Hybrid force and position control has not been achieved as of yet. A passive compliance was added to the end effector to provide a constant force of contact with the task surface.

Methodology—The use of a robot manipulator as an assistive device for a person with disabilities introduces issues of safety and compliant control which are the focus of this project. In such an environment, the manipulator will be needed to perform tasks which require intimate contact with the person and motion control which complies with the environment (i.e., shaving, feeding, etc.). Force sensors present on the robot arm will detect force-of-contact with objects. Strategies will be developed to utilize this force information interactively so as to achieve compliant control.

Preliminary Results—The kinematic and velocity solutions have resulted in a novel control algorithm for the RTX which has application across other manipulator systems. The initial solution utilized a virtual four-bar linkage as a constraint for the links of the RTX. The result was the ability to control the velocity of the tip of the end effector to move about the surface of a sphere while maintaining its orientation directed towards the center of the sphere. This motion is referred to as Target Centered Control and, in addition, reduced the number of degrees of freedom required to control this motion to just two.

The key to the solution is that the reference axes are located in the center of the virtual task sphere. The commands related to the robot are in terms of the task being performed, not in terms of the required motion of the

robot. In this way, an individual may concentrate on performing a task. Eventually, the manipulator will become transparent.

An entire joystick-driven control model has been developed for the RTX based on this approach of task-based minimum degree-of-freedom commands. Task-Oriented Control enables an individual to point the RTX hand at an object, move towards the object, orient about the object, grasp it, and move it to some other location using similar movements. All inputs to the control model are in terms of the task.

Future Plans—The Task-Oriented Control model will be examined in terms of its efficiency and applicability to certain tasks. A number of studies will be performed to determine the extent of task-based control axes. In addition, partitioning and pairing of task axes will be examined to determine appropriate 2-degree-of-freedom task relationships.

The active control of the force exerted by the robot manipulator will be investigated. This Hybrid Force/Position control will be demonstrated on a specially constructed two-link manipulator. Upon successful completion of this device, an active unit will be designed and attached to the end effector.

Appropriate control interfaces will be investigated to match the abilities of a targeted population of disabled users. Not all disabled users of a robot manipulator will be able to control a joystick. Other controllable gestures, such as the motion of the shoulders, or of the head, will need to be identified and evaluated.

Recent Publications Resulting from This Research

- Controlling a Telethesis to Perform Tasks. Crochetiere WJ, 1990 International Conference on Rehabilitation Robotics Conference Papers, Wilmington, DE, 1990.
- Task-Oriented Control of a Robot Manipulator. Mahoney RM, Masters thesis, Drexel University, 1990.
- Task-Oriented Control of a Robot Manipulator. Part I: The Concept. Crochetiere WJ, Mahoney RM, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 299-300, 1990.
- Task-Oriented Control of a Robot Manipulator. Part II: Implementation on the RTX. Mahoney RM, Crochetiere WJ, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 289-290, 1990.

[233] Design of a Small Compliant Robot for Children

William Harwin, PhD; Edward Walsky, BS; Tariq Rahman, PhD; James W. Fee, Jr., MS; Richard Mahoney, MS
Applied Science and Engineering Laboratories, Alfred I. duPont Institute and The University of Delaware,
Wilmington, DE 19899

Sponsor: *Nemours Foundation*

Purpose—Rehabilitation robotics has traditionally looked for complex solutions to the task of giving a person with quadriplegia independence. The common thread in all these projects is to give the robot the same functionality as a human arm (a very remarkable machine designed over several million years). This project proposes a much simpler system based on giving a robot similar functionality to a head-stick and providing force as well as visual feedback for the user. Employing this approach, the user will have a simpler robot that will break down less often. The user will become more effective, and build a strong internal representation of the robot's capabilities.

Most rehabilitation robots are complex, having 5 or 6 degrees-of-freedom. This is understandable given that to grasp an object from an arbitrary orientation requires at least 6 degrees-of-freedom. However, it is difficult to provide the user with a full level of control for a rehabilitation robot of such sophistication because it demands a high level of intellectual ability in the user, or expensive and as yet unrealized technology in the robot. In comparison, although head-sticks are ugly, they provide a person with considerable influence over his or her environment with only 2-degrees-of-freedom.

The proposed project will develop a simple robotic device that can be mounted on a wheelchair laptray. It will have similar functionality to a head-stick, but will operate over a wider volume, not tire the person using it, or cause the obstruction typical of a normal head-stick.

Progress—Several design criteria have already been fixed, the most important of which is the use of a pneumatic drive for the power source. Although a pneumatic drive has several undesirable control characteristics such

as a high degree of hysteresis, the advantage is the built-in compliance, a necessary feature for safety in interactive robotic design.

Methodology—Two prototype systems will be developed. The first is a kinematic prototype that will allow us to evaluate design configurations, the control problem, and a pneumatic system of actuation. This will be constructed using the facilities of the Applied Science and Engineering Laboratories.

A functional prototype will be designed as a result of the information that emerges from the kinematic prototype. This robot will be fully operational and will be manufactured by a third party. While the functional prototype is under construction, the project will investigate Cartesian closed-loop control and suitable interfaces to the robot.

A major aim of this project is to design with safety issues in mind. Many safety issues are not resolved in rehabilitation robotics and it is hoped that this project will be a demonstration of safe design by ensuring fault tolerance and predictable modes of failure. The United Kingdom Department of Trade and Industry has begun setting up safety guidelines for interactive robotic systems; the U.S. will have to begin a similar process in the near future.

Future Plans—The short-term benefits are to see how a simple robot can best be used to assist a person with a physical disability, and to evaluate the safety design criteria that are involved. The long-term benefits are to promote the sense of independence for children with disability, by providing a direct means of interaction with the environment.

[234] Quantification of the Effective Manual Dexterity Skills of Users of Rehabilitation Robotics Systems

Richard Mahoney, MS; Tariq Rahman, PhD

Applied Science and Engineering Laboratories, Alfred I. duPont Institute and The University of Delaware, Wilmington, DE 19899

Sponsor: *Nemours Foundation*

Purpose—Robot manipulators have shown great promise as assistive devices for the disabled. Many methods have been developed to enable an individual to control a manipulator to aid in manipulation of his or her environment. However, no standardized approach has been provided which allows for a quantitative evaluation of these methods.

This project proposes the development of a standard test which will enable a quantitative assessment of the effective manual dexterity of a rehabilitation robot. The effective manual dexterity of a rehabilitation robotics system is defined as those manipulation skills an individual exhibits while controlling the system interactively to perform dexterous tasks.

The test will be independent of the manipulator being used, the input device driving the manipulator, and the level of disability of the user. The test will be based on standard tests which are currently being used in the field of occupational therapy. In this way, comparisons may be made between existing norms.

Progress—Several standard tests of human manual dexterity skills have been identified. The tests chosen are applicable because they involve testing the skills of one hand. These tests are the Jebsen Hand Test, the Minnesota Manual Dexterity Test, and the Box and Blocks Test.

Methodology—The overall objective is the development of a standard test which will assess the effective manual dexterity skills of an interactively controlled manipulator. Subtasks required to achieve this goal are: 1) investigation of existing tests of human motor function: current tests which are used in the field of occupational therapy to assess the level of manual dexterity skills will be inves-

tigated. Occupational therapists will be the main resource; 2) determination of the applicability of these tests to a rehabilitation manipulator: once a set of tests has been identified, they will be considered in terms of their ability to provide reasonable data if used to evaluate the "manual dexterity" of a manipulator. If appropriate, the tests will be used as is. If not appropriate, modification to the test will be considered, which may increase its applicability; and, 3) administration of the test: once the details of the tests have been finalized, actual tests will be carried out in order to compile a base data set and test the reasonableness of the test. These trials will be carried out with able-bodied persons using a to-be-determined level of control.

Preliminary Results—This project is currently in the planning stage and no significant results have been achieved as of yet.

Future Plans/Implications—The investigators intend to investigate the developed test as a research tool in the rehabilitation robotics field. There are several areas where this test may be applicable.

It may be possible to develop a relationship between scores obtained on this test and the ability of an individual to perform ADL tasks using a rehabilitation robotics system. In the same way, an individual's progress with the system may be monitored by administering the test at significant intervals. It may also be possible to use the scores from this test to evaluate and compare different aspects of one system.

Ultimately, the testing scheme which may result from this project could form an integral part of the overall assessment and evaluation of rehabilitation robotics systems.

[235] Quantitative Evaluation of Voice-Controlled Robotic Manipulation for Rehabilitation Purposes

David M. Horowitz, SM; Jeffrey M. Hausdorff, SM

Rehabilitation Engineering Program, Department of Rehabilitation Medicine, Tufts University School of Medicine, New England Medical Center, Boston, MA 02111

Sponsor: Office of Special Education Programs, U.S. Department of Education

Purpose—A voice-controlled vocational robotic workstation known as VoiceMOVES was developed to suit the vocational needs of individuals with motor disabilities. A user-intuitive human-machine interface which functions as a voice-commanded robot programming language was designed, implemented, and tested. The interface was designed to enable the technically nontrained individual to customize and command a robotic manipulator. Although many qualitative accounts of various approaches in rehabilitative robotics exists, very few adequate quantitative assessments of human productivity have been proposed. The purpose of this study was to evaluate the feasibility of having technically nontrained individuals learn how to program a robotic manipulator and evaluate the accuracy and efficiency of the robotic system that we developed.

Methodology—VoiceMOVES incorporates a Universal Machine Intelligence RTX robotic manipulator and a Kurzweil Voice System 1000 word recognizer. An expert system manages the user's dialogue with the programmable robotic manipulator and speech recognizer. A knowledge base is maintained that contains a model of the robot's world by associating sequences of motions with phrases the speech recognizer accepts. The system functions as a Robot Motion Editor, allowing the user to edit the knowledge base.

Results—Eight subjects were trained to use VoiceMOVES. Four of the subjects were technically literate. The other four were technically naive. Each subject received over 30 hours of experience with VoiceMOVES. A subject's performance was analyzed with respect to the time it

took to complete a task. Three tasks were studied: manipulation of a cup, a tissue, and a book. Voice recognition accuracy and robot motion planning time were analyzed. A preliminary evaluation of the results indicate that there was no difference in performance between the technically trained and technically naive subjects. These results indicate that a robotic workstation which allows end-users to customize the robot motions is an effective design for a rehabilitation robotic workstation. Users can learn to safely and effectively pilot a robot manipulator. An approach which allows end-user programming of a robot is expected to be more cost-effective, minimizing the need for technical support from an engineer.

Recent Publications Resulting from This Research

- Design of a Human-Machine Interface of a Voice-Controlled Vocational Robotic Workstation. Horowitz DM, Hausdorff JM, in Proceedings of the 12th Annual RESNA Conference, New Orleans, LA, 117-118, 1989.
- Discussant Response. Horowitz DM, Hausdorff JM, in Proceedings of the First International Conference on Rehabilitative Robotics, A.I. duPont Institute, Wilmington, DE, 1989.
- Sensory Feedback and Automated Grasping for a Vocational Workstation. Hausdorff JM, Horowitz DM, Carroll SS, in Proceedings of the 12th Annual RESNA Conference, New Orleans, LA, 183-184, 1989.
- The Structure and Function of a Speech Control Language for Text Processing and Robotic Control. Horowitz DM, Hausdorff JM, in Proceedings of the 11th Annual International IEEE/EMBS Conference, Seattle, WA, 1757-1797, 1989.
- A User-Intuitive Speech Control Language for Text Processing and Robotic Task Planning. Horowitz DM, Hausdorff JM, J Am Voice I/O Soc 6:28-46, 1989.
- Preliminary Evaluation of a Voice-Controlled Robotic Workstation. Hausdorff JM, Quintin E, Horowitz DM, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 125-126, 1990.

[236] Rehabilitation Robotics/Man-Machine Interface Laboratory

Gerald E. Miller; Bradley D. Etter

Texas A&M University, Bioengineering Program, College Station, TX 77843-3120

Sponsor: *Texas Department of Mental Health and Mental Retardation; National Aeronautics and Space Administration; Texas Advanced Technology Research Program*

Purpose—This research involves the development of a real-time, flexible control system for rehabilitation/assistive robots for use by disabled individuals. The control system is based on both voice recognition capabilities and an infrared sensor system placed within the robot grippers. This system is designed to augment menu-based, fixed-task robot functions by providing flexible motion and gripping controls for instances where preprogrammed tasks are inappropriate. This would include tasks that are not on the preprogrammed menu or emergency settings where rapid, flexible controls are required.

Progress—The voice recognition system is based upon modified commercial systems, including those by Dragon Systems and Votan Voice Systems. Recent research in voice recognition for a disabled population has centered on the ability of such systems to recognize slurred speech common to many disabled individuals with poor motor and vocalization skills. In addition, several methods to analyze and subtract ambient noise have been studied in order to optimize the voice recognition system design. Methods to integrate a flexible, voice activation system into other menu-driven, fixed-task systems have also been analyzed. The infrared sensor system has been designed and tested to provide automatic gripping of nearby objects. This function is elicited by a single voice command and produces a gripping function of both stationary and moving objects. A neural network control system is being analyzed to incorporate both voice and infrared data into a robot motion/gripper control scheme.

Results—The voice recognition system has been tested for a wide variety of speech abnormalities and accents. The commercially based systems have been modified to incorporate several speech classifications resulting from various disabilities. Several sources of ambient noise have been analyzed for amplitude and frequency content. Various electronic and computational noise cancellation

procedures have been developed as integral components of the modified voice recognition system. The infrared gripper control system has been designed, constructed, and tested on several types of small robots. Initial tests have demonstrated the ability to grip objects up to 18 inches from the gripper for both static and moving targets. The gripper system consists of many infrared emitters and receivers that determine the location and range of the target and controls the robot motion and gripping function to grasp the nearest object.

Future Plans/Implications—The voice recognition component to the overall robot control system is to be analyzed for potential integration with existing fixed-task, preprogrammed robot controllers in development at other rehabilitation research centers. The infrared gripper system will be tested for a wide variety of ambient conditions including light, target color and shape, target motion, and range from target to gripper. A neural network control algorithm is being continually studied to optimize robot motion and gripping function. The overall goal is to develop a flexible control system which can serve as an adjunct to fixed-task systems. The flexible version is being developed to allow disabled individuals and their assistive robots to cope with emergency situations where preprogrammed tasks cannot provide adequate support.

Recent Publications Resulting from This Research

Analysis of Voice Processing for the Control of Devices to Aid the Disabled. Miller GE, Etter BD, Bartholomew JC, in *Proceedings of the 12th Annual RESNA Conference*, New Orleans, 410-411, 1989.

Automated Grasping Aided by Optoelectronic Sensors. Etter BD, Duck MR, Seaman RL, *IEEE Transactions on Robotics and Automation*, 1990.

Man-Machine Interfaces for the Disabled. Miller GE, in *Advances of Bioengineering, Proceedings of ASME Winter Annual Meeting*, 1990.

Voice Controls for Manufacturing Environments. Etter BD, Miller GE, *Manufacturing Review* 2(4):242-249, 1990.

C. Communication Methods and Systems

[237] Computer Keyboard Emulation Through Interpretation of Pointing Gestures

Tom Nantais, BASc; Morris Milner, PhD, PEng, CCE; Henry O'Beirne, MA, MASc; Fraser Shein, MEng, PEng
Hugh MacMillan Rehabilitation Centre, Toronto, Ontario M4G 1R8 Canada

Sponsor: Bloorview Children's Hospital Foundation

Purpose—A new keyboard emulator is being developed for people with severe motor impairments. The objective has been to have the system imitate a human listener in an augmentative communication setting. The motivation is that previous successful human/machine interfaces (i.e., the mouse), have been based on some metaphor with another activity in which its intended users have had experience (in this case, face-to-face communication with another person through a direct selection communication board).

Methodology—For the system to imitate a human listener, it must be able to track and interpret pointing gestures. An infrared CCD camera-based tracking system has been converted to track a single retroreflective marker which the user typically wears on the fingertip. The sensor is mounted directly above the communication board and reports the marker position in two dimensions at a rate of 30 samples per second. The position information is communicated to an IBM PS/2 Model 30 286. The user's selection set is printed on the communication board and the location of the center of each element (e.g., letters, combinations, commands, etc.) is stored on the PS/2.

The system is being designed to collect and use information in two distinct areas. The first area is the patterns of characters the user typically enters. A Markov Model produces a probability distribution for the next character to be entered. The probability distribution is used to lower the acceptance standards for elements that would seem probable and make unlikely characters correspondingly more difficult to enter. A dictionary tree structure is maintained in the system for automatic completion of words with those unique endings that the user has entered in the past.

The second area of customization involves trajectories taken in the targeting motions that lead to the selection of communication elements. The technique is based on a connectionist pattern associator using an error

back-propagation learning rule and normalized exponential output units. Sets of position samples from labeled trajectories are used in a training phase to customize the associator to the user's qualities of motion. After training, when a new trajectory is input, the system responds with a probability distribution for destination. Experimentation is in progress (with this general arrangement) with a nonimpaired subject, and an associator has been trained that can predict destination correctly in 72% of the training cases.

Preliminary Results—Early experimentation has shown the importance of automatic customization to the qualities of a particular user. The study involved two persons with motor impairments to the degree that they use a direct selection letter board for communication with another person. The participants were shown several messages on a television screen, which they were instructed to communicate to another person using their letter boards. In half of the trials, the listener was someone with whom the person regularly communicated, and who was familiar with the qualities of the communication process. In the other half, the listener was a stranger. Messages could either be a series of random characters or a complete sentence. For the sentences, the familiar listener could interpret the gestures as much as twice as quickly as the unfamiliar listener. For the random character strings, the results were less distinguishable. The results support the idea that a system which can gain long-term experience serving a particular user will be more successful than a generic, static design.

Future Plans—Future work will focus on the combination of these two areas of customization into an overall system capable of making realistic predictions of the next element that a given user intends to communicate. A single-subject study is planned, using a crossover design to compare the user's net rate of input with this system, with that of the user's prescribed written-communication device.

[238] Computer Interpretation of Gestures Made by the Severely Disabled

Alistair Y. Cairns, BSc

Microcomputer Centre, Dundee University, Dundee DD1 4HN Scotland

Sponsor: *Dundee University*

Purpose—Our purpose is to investigate free arm movement or gestural control of computer-based aids by the severely disabled. People with disabilities have problems producing discrete movement (e.g., hitting a switch), or serial movement tasks (e.g., pointing) necessary for the control of computer-based aids. In an attempt to overcome these problems, we intend to harness the repertoire of arm movements (or gestures) available to a particular subject. Computer recognition of the different gestures available to each subject will allow control of computer systems via gestures and remove or reduce the problems inherent in some conventional input systems.

Progress—Work is ongoing to develop a computer-based gesture recognition system.

Methodology—Examples of arm gestures have been collected from a number of subjects using a commercially available position-monitoring device. No restriction was placed on the types of movements that could be made by the subject. The movements were collected over a period of a few weeks, and recorded on computer. A number of examples of each movement type that the subject could perform were recorded during each session.

Signal processing and pattern recognition techniques will be used to analyze and classify each different movement that was made.

Results/Future Plans—Work is ongoing, with future plans for development of a real-time gesture recognition system and evaluation of its usefulness as an access methodology.

[239] A Blackboard Expert System Approach Toward Implementing an Adaptive Force Joystick Computer Input Device for the Tremor Disabled

Rod McGill

Hugh MacMillan Rehabilitation Centre, Toronto, Ontario M4G 1R8 Canada

Sponsor: *Easter Seal Research Institute of Ontario*

Purpose—The long-term goal of this project is to develop expert system software which will help disabled persons to configure and maintain proper settings on their computer input devices on a daily basis. The short-term goal has focused on screen-based tracking tasks performed by persons with tremor disability using a force joystick input device. We believe this to be a good starting point for the adaptive problem due to the day-to-day variation in tracking ability which can occur with this population. The force joystick provides a solid anchor point for the tremor-affected hand and can be used to filter tremor using digital filtering routines.

One problem that arises when trying to perform any adaptive actions is that of how to define tracking performance such that the “goodness” of tracking has meaning. A second problem is that of selecting the proper joystick parameters so that performance is best with respect to tradeoffs between accuracy of tracking, speed, effort, tremor level, and other more vague properties such as

joystick “feel.” Any successful adaptive interface must address these problems and it is here that the current research is focused.

Methodology—There are different viewpoints that can be taken when considering how tracking performance should be defined and measured in order to determine the force joystick parameters which result in good tracking. These viewpoints range from an expert therapist’s qualitative assessments to employing various computer-based numerical measures. Each viewpoint results in a different performance assessment and associated proper joystick filter setting: the proper filter settings across the different viewpoints form a fuzzy set.

A study of how to combine the information to reduce the fuzziness in the solution is currently being conducted. Four different viewpoints of handling the tracking performance problem—knowledge source (KSs), are being used together in a blackboard expert system framework.

Knowledge sharing between the various KSs can occur at different blackboard levels and between different combinations of KSs. The level at which KSs share knowledge affects the degree of fuzziness in the resulting performance evaluations and filter parameters sets. The KSs in use within the framework are: 1) ARMA modeling; 2) spectral analysis; 3) a potpourri of operational definitions of performance; and, 4) an expert therapist's evaluation.

Progress—A blackboard expert system has been written in LPA MacProlog 3.1 using the FLEX expert system toolkit. Numerical processing routines were written in Lightspeed Pascal 3.0 and linked into the blackboard as Prolog predicates. The expert system runs on Macintosh II

and the screen tracking tasks run on a Macintosh SE/30 which is networked to the expert system over TOPS. To date, a simple pilot study has been conducted on three tremor-disabled subjects and five nontremor subjects.

Results—The pilot study results have shown that each KS can evaluate tracking performance and determine joystick gains independently with varying degrees of success.

Recent Publications Resulting from This Research

A Blackboard Knowledge-Based Approach Towards Implementing and Adaptive Force Joystick Computer Input Device for Persons with Tremor Disability. McGill RA, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 431-432, 1990.

[240] Formation and Modification of Attitudes Toward Young Augmentative Communication Device Users

Bernard M. O'Keefe; Pauline H. Parnes, BSc, DSPA; Kingsley Bower, MHSc; Lorelee MacLean, MHSc
Graduate Department of Speech Pathology, University of Toronto, Toronto, Ontario M5G 1L4 Canada;
Augmentative Communication Service, Hugh MacMillan Rehabilitation Centre, Toronto, Ontario M4G 1R8 Canada

Sponsor: *Easter Seal Research Institute of Ontario*

Purpose—The attitudes which nondisabled speakers hold toward teenage and young adult nonspeakers who use augmentative and alternative communication (AAC) assistive devices to communicate may strongly influence the opportunities of such users. This investigation is designed to determine if the various ways assistive devices deliver messages influence the attitudes of non-disabled speakers. A method for improving attitudes is also being investigated.

Methodology—The project is comprised of two studies. The first seeks to determine if the type of conversational

relationship which able-bodied speakers have with a young AAC device user affects the attitudes of the able-bodied speakers. The second study seeks to determine the effects of four different outputs on the attitudes of the able-bodied speakers toward the AAC users. The second study also tests the use of a simple method for improving such attitudes. Both studies employ similar procedures.

Results—The results of the relationship study will determine the extent of the external validity of the output study.

[241] A New Approach to Augmentative Communication Services with Synergy Between a Central Resource of Expertise and Community-Based Programs: **A. Implementation**

Pauline H. Parnes, BSc, DSPA

Augmentative Communication Service, Hugh MacMillan Rehabilitation Centre, Toronto Ontario M4G 1R8 Canada

Sponsor: *National Health Research and Development Programme, Department of Health and Welfare, Canada*

Purpose—This project proposes a model of service delivery which attempts to address the conflicting demands of a centralized "center of excellence" approach with the needs for community involvement

and support. The proposed model is offered as a potentially generalizable model for the delivery of rehabilitation services and other long-term health related services.

The model is based on several key principles, including: more focused intervention; development of local resources; increased empowerment of local personnel; increased independence of consumers; reduction of waiting list; and, increased job satisfaction for staff.

Methodology—Many aspects of the service delivery model outlined in this proposal will be implemented on a 2-year pilot basis through resources available at the Augmentative Communication Service (ACS) of the Hugh MacMillan Rehabilitation Centre. The program evaluation component of this project will be conducted through the leadership of an independent evaluator. The evaluation component has been submitted as a companion proposal to allow for process as well as outcome evaluation approaches.

Preliminary Results—A new model of service delivery has been developed in an attempt to build on the strengths of the existing model, and to address the following key issues: 1) more focused, and therefore more effective, intervention. Allowing staff to work with a fixed number of clients per year will allow ACS staff to focus their energies to provide more effective intervention rather than doing a little for many clients. The set period of intervention time (e.g., one year), as opposed to the previous open-

ended time line, will allow better planning and organization of assessment and intervention goals; 2) development of local resources. Stronger links with the community will provide clients with the community-based services essential to successful integration into local environments; 3) greater empowerment of facilitators and local professional teams. The intensive instruction of facilitators and local teams carried out gradually over a long period of time will be much more effective in terms of providing them with the skills and information required to become more informed participants in the rehabilitation process; 4) increased independence for users and families in terms of deciding what level of intervention is appropriate at various times in their family life. Eventual reduction of the dependency of users on major health care agencies and training in self-advocacy are seen as potential long-term goals; 5) impact on the waiting list. This model will allow ACS to minimize the waiting list and to accelerate provision of services for clients who previously may have waited up to 2 years for service; and, 6) greater job satisfaction. The concept of seeing progress over a definite period of time relative to realistic goals will decrease frustration of staff who feel they can “never do enough.”

To address these key issues, the new model will be implemented for a 2-year period with a view to evaluating its effectiveness.

[242] A New Approach to Augmentative Communication Services with Synergy Between a Central Resource of Expertise and Community-Based Programs:

B. Evaluation

Kathryn Boschen, PhD

Department of Rehabilitation Medicine, University of Toronto, Toronto, Ontario M5T 1W5 Canada

Sponsor: National Health Research and Development Programme, Department of Health and Welfare, Canada

Purpose—The purpose of this project is to evaluate the new ACS model of Service delivery (see “A New Approach to Augmentative Communication Services with Synergy Between a Central Resource of Expertise and Community-Based Programs: A. Implementation,” p. 192).

Methodology—The proposed evaluation of the new ACS model of service delivery will take advantage of an information-collection system already in place within the department. In addition, two other data-gathering instruments will be developed specifically for the evaluation.

The approach will comprise both a process and an outcome evaluation. Input will be provided from all three groups involved with the service: 1) service consumers and/or their parents and facilitators; 2) ACS service provision staff; 3) Level 1 and 2 augmentative communication clinic personnel (authorized by the Assistive Devices Program).

The focus of the evaluation will be on examining the items which prompted the development and introduction of the new service delivery model, in particular those listed under the goals of the new service delivery model: 1) effectiveness of intervention; 2) development of local

resources; 3) greater empowerment of facilitators and local professional teams; 4) increased independence for users and families; 5) impact on the waiting list; and, 6) greater job satisfaction for ACS staff.

Progress—Specific preimplementation data have already been, or are currently being collected, and will provide the baseline information for the evaluation.

[243] Development of a Universal Communication Aid: LUCY

Bernard Visse; Henk G. Stassen; Jan Goezinne

Man-Machine Systems Group, Laboratory for Measurement and Control, Faculty of Mechanical Engineering and Marine Technology, Delft University of Technology, 2628 CD Delft, The Netherlands

Sponsor: *Innovative Research Programme for the Disabled/Aids for the Handicapped; Foundation for the Development of Communication Aids for the Handicapped; OSKAR; Lions Club, Delft; Ministry of Social Affairs*

Purpose—The overall purpose of this project is to develop and realize a universal communication aid for a broad class of disabled people. Therefore, starting with the Lightspot-Operated Typewriter (LOT), designed especially for quadriplegics, a new communication system, called LUCY, was developed. Presently, LUCY functions as a replacement for a PC-keyboard, as well as a control device for a standard PC-printer or speech synthesizer.

Methodology—LUCY consists of a panel with a height of 236 mm and a width of 282 mm, representing a character display and a matrix of 8×11 cells. With the help of the cells, the user can select one of the characters and send it to one of the above-mentioned devices. LUCY can be used in two different control modes: as a matrix communicator, and a direct lightspot selector.

When used as a single-switch matrix communicator, the rows light up one by one. When a row containing the character to be selected lights up, the switch must be activated. Next, the cells in the row light up one by one. The desired character can be selected by activating the switch again when the corresponding cell lights up.

When using LUCY as a lightspot-operated system, the input device consists of a light pointer which can be mounted on a pair of spectacles. The light pointer gener-

ates a red spot on the panel, and the character is selected by exposing a cell for a user-adjustable time. The lightspot detection unit is only sensitive to modulated red light from the light pointer, so the system can be used even in a highly illuminated room.

The character generated is sent to either a personal computer or the character display. When using a printer or speech synthesizer, the user can edit the characters in the display, and send the text to the output device when the sentence is completed.

Progress—This year, the prototype of LUCY was further developed so that it is now commercially available (Shannon Electronics, Zoetermeer, The Netherlands).

Future Plans/Implications—In the future, other input devices will be available. The main advantage of this communication aid is its flexibility. The possibility of selecting different input and output devices creates the opportunity to use LUCY in numerous applications, from recreative purposes up to professional computer usage in industry. This flexibility also makes it possible to adapt LUCY to all stages of any degenerating disease, so that the patient can use LUCY first as a lightspot-operated device, and later as a matrix communicator.

[244] Speech Synthesis Program

Debra Yarrington, BA; Richard Foulds, PhD; Fred T. Beam, BS; Pamela J. Trittin, BS

Applied Science and Engineering Laboratories, Alfred I. duPont Institute and The University of Delaware, Wilmington, DE 19899

Sponsor: *National Institute on Disability and Rehabilitation Research; Nemours Foundation*

Purpose—The purpose of this program is to create high quality, unrestricted, multilingual synthesized speech in a number of different voices.

Methodology—This program can be partitioned into four projects. These are: 1) development of a software diphone synthesizer; 2) development of an automatic diphone

extractor; 3) generation of a bilingual speech synthesis system based on English and Spanish; and, 4) production of a hardware speech synthesizer.

The software synthesizer will use diphones as its units of synthesis because diphones allow unrestricted vocabulary while providing high quality, intelligible speech. Diphones are speech segments that run from the steady state of one phoneme to the steady state of another, capturing the transition between phonemes. The diphones are recorded in carrier words and then manually extracted and stored. The process of creating a complete library takes approximately 6 months.

Once the library has been completed, it must be used in conjunction with an algorithm that converts written text to synthesized speech. This text-to-speech algorithm is used in conjunction with an algorithm that partitions text into syllables with stress markers. With this information, pitch contours can be imposed upon the synthesized utterance. This increases its intelligibility and naturalness.

In order to create a synthesizer that allows the voice of choice, an automatic diphone extractor is being developed. The automatic extractor uses the original library for template matching, plus rules based on the spectral analysis of the recorded speech. With it, a nonvocal person will be able to choose the voice and dialect with which he/she wishes to communicate.

To further extend the population of nonvocal users, a bilingual speech synthesizer is being developed. This project includes the development of a Spanish text-to-speech algorithm using Spanish phonemes, the creation of an inventory of Spanish diphones, and the development of a set of rules for syllabifying Spanish words. The final subproject is the development of a hardware speech

synthesizer. This hardware synthesizer must be portable, lightweight, flexible, and efficient.

Preliminary Results—Currently, a speech synthesizer with a child's voice is being developed. The text-to-speech algorithm has been updated, and is undergoing final corrections. The automatic extractor functions well with a number of phonemic combinations. Work is now being done with a new method of extraction that should yield higher quality results. Rules for a Spanish text-to-speech algorithm have been completed, as well as rules for syllabifying Spanish words. Currently, a Spanish inventory is being developed.

Future Plans—Future plans include final work on the text-to-speech algorithm, along with further development of the syllabifier, the completion of the automatic diphone extractor to allow for the creation of a number of different synthesized voices, the completion of a Spanish synthesized voice, and the production of the hardware diphone synthesizer.

Recent Publications Resulting from This Research

- New Methods for Pitch Change During Time-Domain Waveform Coded Diphone Speech Synthesis. Yarrington D, Jones M, Foulds RA, in Proceedings of the 12th Annual RESNA Conference, New Orleans, LA, 220-221, 1989.
- The Synthesis of High Quality, Human Sounding Speech. Yarrington D, in Official Proceedings of Medical Applications of Voice Response Technology, Pittsburgh, PA, 1989.
- Improvements in Synthesized Speech Using Time-Domain Waveform Coded Diphones. Yarrington D, Schlemmer J, Foulds RA, in Proceedings of the 1990 AVIOS Conference (in press).
- Personalizing Voices for Non-Vocal Individuals. Yarrington D, Trittin P, Beam F, Commun Outlook 12(1) (in press).

[245] Personal Computer-Based Augmentative Communication Systems

Lorie J. Miller, MS; Patrick Demasco, MS; Cathy J. Rookard, MS; Beth Mineo, PhD; Michael Thompson, BS
Applied Science and Engineering Laboratories, Alfred I. duPont Institute and The University of Delaware, Wilmington, DE 19899

Sponsor: National Institute on Disability and Rehabilitation Research; Nemours Foundation

Purpose—The purpose of this project is to develop prototype personal computer (PC)-based augmentative communication systems. The PC-based approach allows more flexibility, configurability, and ease of updating.

Progress—A PC-based communication system, named Meta4, has been designed for use with desktop or laptop

computers that support MS-DOS. In addition to the actual communication software, supporting utilities have been created to facilitate easy modification and customization of the system. At present, there are four utilities under development: 1) abbreviation/expansion utility; 2) vocabulary management utility; 3) configuration utility; and, 4) usage analysis utility.

Each utility is designed to make maintenance and updating of the system as simple as possible. They also provide a convenient interface to all the flexible features of Meta4.

The vocabulary management utility is a valuable addition to this package. This utility provides full flexibility in designing and maintaining a user's vocabulary set. Two features make this utility particularly user-friendly. First, the program utilizes a drop-down menu system used by many commercially available software packages. Second, the program presents the contents of the vocabulary set exactly as Meta4 does. This allows the vocabulary to be viewed in the same way they appear to the user. Both of these features are aimed at creating an interface that is familiar to the user, making the program easier to use.

One of the most unique features of Meta4 is its ability to track and analyze data. The program automatically records each selection made by a user. This information can later be analyzed using the support utility and can provide valuable insight into the efficiency with which the device is being used. This analysis can also guide the clinician or user in updating the system for the user's changing needs. At present, work is concentrating on the presentation of the data in ways that can be quickly and easily understood.

Preliminary Results—At this time, Meta4 is being used as a functional communication device for one test subject. This subject uses Meta4 on a Toshiba laptop computer for daily communication needs. Researchers on the project continue to be guided by the feedback from this subject.

All of the support utilities have reached prototype form and work is continuing to refine their function and interface to the user.

Future Plans—Meta4 will soon be available for transfer out of the laboratory. Communication is continuing with manufacturers on the potential for Meta4 to be developed as a commercial product.

Recent Publications Resulting from This Research

Automatic Data Collection and Analysis in an Augmentative Communication System. Miller LJ, Demasco PW, Elkins RA, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 99-100, 1990.

A Human Factors Approach to Vocabulary Management for an Augmentative Communication Device. Rookard CJ, Thompson M, Mineo BA, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 101-102, 1990.

[246] Development of an AAC Software Architecture

Patrick Demasco, MS; J. Eugene Ball, PhD; John Dunaway, BS

Applied Science and Engineering Laboratories, Alfred I. duPont Institute and The University of Delaware, Wilmington, DE 19899

Sponsor: *National Institute on Disability and Rehabilitation Research; Nemours Foundation*

Purpose—The goal of the Architecture Project is to facilitate more cost-effective development of Augmentative and Alternative Communication (AAC) application software by developing a general framework for describing AAC systems and a supporting set of tools that will allow other developers to produce new applications. This will effectively minimize duplication of efforts in a field where resources are precious, and promote sharing of ideas and software among developers. By utilizing object-oriented software technology, it is possible to develop a set of building blocks that can be used to realize this goal.

Methodology—The use of object-oriented analysis, design, and development provide significant advantages toward reusable software. Specifically, we have chosen the C++ language for its elegant support of the OOP

paradigm, its efficiency, and for its wide availability in the marketplace.

Progress—The architecture under development consists of two major components. LASO (Library of Adaptable Software Objects) is a set of C++ class hierarchies. Each hierarchy represents a functional AAC system component. For example, the *Vocab* class supports a flexible vocabulary set structure. LASO has been designed to maintain maximum independence between class hierarchies. This allows developers to use as many or as few of the system components as desired.

The second major component of the architecture is the *Adapt* authoring language. This language, which is based on LOGO, provides three major functions. First it supplies a high-level approach to providing interconnections

between system components and provides an overall description of application function. Second, *Adapt* scripts can be associated with key activations to provide the user with a powerful command language. Finally, the script language could be used to implement unique selection methods.

Future Plans—We plan to continue design and development on both system components and hope to have a distributable release of the toolkit within the next year.

[247] Rate Enhancement Through Sentence Compansion

Patrick Demasco, MS; Kathleen F. McCoy, PhD; Mark Jones, MS; Christopher Pennington, MS; Gregg Stum, BS
Applied Science and Engineering Laboratories, Alfred I. duPont Institute and The University of Delaware, Wilmington, DE 19899

Sponsor: *National Institute on Disability and Rehabilitation Research; Nemours Foundation*

Purpose—The goal of this project is to increase the communication rate of physically disabled individuals via natural language processing techniques. We wish to take as input a compressed message (i.e., uninflected content words) from the disabled individual, and yet pass a syntactically and semantically well-formed utterance to a speech synthesizer or text preparation system. At the same time, we wish to do this by placing as little a burden on the user as possible. Thus, we are not interested in a simple coding system where sentences have been stored and are indexed by their content words.

Progress—The present system has a vocabulary of over 400 words. It handles most tenses, produces a variety of sentence constructions, and has the capability to infer the verb or subject in some situations.

Methodology—Input to our system are the uninflected content words of an utterance; thus, many function words such as determiners (e.g., the, a) and prepositions (e.g., of, in) will be left out. The system is responsible for filling in missing words as well as correctly conjugating the verb and forming a syntactically correct utterance. We attempt to form an utterance whose word order most closely reflects the word order given in the original input the user wishes to convey. For example, if the system is given "APPLE EAT JOHN," we would like the system to produce the sentence, "THE APPLE IS EATEN BY JOHN." In order for the system to generate a well-formed

Recent Publications Resulting from This Research

- Adapt: An Authoring Language for a Flexible AAC Architecture. Ball JE, Demasco P, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 179-180, 1990.
- Determining Future Software Requirements for Augmentative Communication Systems. Demasco P et al., in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 337-338, 1990.
- A Software Object Library for Augmentative Communication Systems. Demasco P, Ball JE, Kerly P, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 350-351, 1990.

utterance, it employs a semantic parser to form a semantic representation of the input words. In this example, the parser recognizes that EAT can be a verb which accepts an animate ACTOR and an inanimate/food OBJECT in order to correctly infer the semantic relationships between these input words. The resulting semantic representation (along with a specification of the original word order) is then passed to the translation component which is responsible for replacing the semantic terms with their language-specific instantiations. The final phase of the processing is a sentence generator which attempts to form a syntactically correct sentence that retains the general order of the original input words.

Future Plans—Areas for further improvement include allowing for more complex sentence constructions, a richer vocabulary, and making use of discourse information. In addition, we have recently begun a collaboration with a Semantic Compaction and Prentke Romich to transfer this technology into a "scaled-down" system.

Recent Publications Resulting from This Research

- Applying Natural Language Processing Techniques to Augmentative Communication Systems. McCoy K et al., in Proceedings of the 13th International Conference on Computational Linguistics, Helsinki, Finland, 413-415, 1990.
- A Domain Independent Semantic Parser for Compansion. McCoy K et al., in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 187-188, 1990.

[248] A Force-Sensing Resistor Switch for Use by Handicapped Children

Subrata Saha, PhD; Paul Williams, BS; J.A. Albright, MD

Department of Orthopaedic Surgery, Louisiana State University Medical Center, Shreveport, LA 71130

Sponsor: National Science Foundation

Purpose—Single switches are often used by handicapped children to operate communication and educational aids, computers, environmental controls, and mobility aids. Severe motor-impaired students often have difficulty controlling the amount of force that is applied to such a switch. The result is a “wearing down” of the sensitivity of the switch. Other students, however, may not elicit an adequate amount of pressure to activate the switch. This points out the need for a pressure-sensing switch that can be adjusted to control the threshold force necessary to activate the switch. In this study, we have used a commercially available force-sensing resistor (FSR) to build such a switch.

Methodology—The FSR is a polymer film device that exhibits a decreasing resistance with increasing force that has been developed for several applications (one being human touch control). Due to the various characteristics of the FSR, as well as its small thickness (<0.5 mm),

these devices made by Intertink Electronics are available in a variety of shapes and sizes. We have built a circuit that allows the FSR to be used as a simple force-adjustable switch. The comparator circuit allows for the sensitivity of the switch to be adjusted to accommodate the specific needs of the child. This adjustment is done by adjusting a 20 K ohm potentiometer. As force is applied to the surface of the FSR, the voltage of the comparator decreases, and when the voltage at pin 9 reaches a value equal to or less than the present voltage, the relay is activated, turning the device on. Additional devices (such as a timer device) can be connected, or additional circuitry can be included in the device to facilitate added capabilities.

Results—The first force-sensing resistor switch was built with a small (15 mm diameter) FSR element. This has been used by a few normal volunteers and will soon be used by several motor-impaired students at the Caddo School for Exceptional Children.

[249] Development of Input Interfaces for Handicapped Children

Paul A. Williams, BS; Subrata Saha, PhD; E.N. Roots

Department of Orthopaedic Surgery, Louisiana State University Medical Center, Shreveport, LA 71130;

Department of Electrical Engineering, Louisiana Tech University, Ruston, LA 71272

Sponsor: National Science Foundation

Purpose—This project has been initiated to design and implement a group of input modules (input interface devices) which will augment/assist the ability of a handicapped child in operating devices and/or systems to perform various tasks requiring single input(s). This work is part of a larger project to develop electronic devices to aid handicapped children.

Progress/Methodology—Based on investigations, some of the requirements for an interface device were that the device should be: 1) flexible (different sensor options for different needs and capabilities); 2) small and compact in size; 3) rugged; 4) able to interface with a variety of devices or systems; and, 5) easy to use without being restrictive to the child. There are few,

if any, commercially available devices that meet all of these requirements.

One of the first observations was that although some children could not consistently apply a specific amount of force to a switch, they usually could maintain a specific position. Using the capacitance of the body, it was possible to utilize a capacitive proximity device as an input sensor. A commercially available proximity device, obtained from a local manufacturer, performed satisfactorily in that the children were able to activate the switch reliably and with little difficulty. However, this switch was relatively expensive due to the industrial requirements which exceeded our needs; it also used an AC power supply which was not ideal for school use. This prompted us to design a proximity

device which would operate on batteries and be relatively inexpensive.

We also observed that each individual child appeared to be able to produce a particular activation force that they could consistently apply. Yet, most devices in use were designed for a single activation force. A switch with a variable activation force could be very advantageous. Such a switch was designed using a force-sensing resistor (FSR) which is an extremely thin (1 mm or less) sensor composed of a conductive polymer that changes resistance with force. In comparison to the microswitches normally used, the FSR could potentially be a much thinner switch with a large surface area, without the use of a lever or a large plate.

Results—The proximity device prototype, and the FSR prototype, have been in use at the Caddo School for Exceptional Children for nearly one year and have proven to be useful and advantageous. Additionally, information has been obtained from the field test leading to enhancements and improvements to the devices.

Future Plans—This is the first stage of a larger project to develop a family of devices which will allow for optimal interfacing between the child and the assistive device. One of the desirable requirements was wireless connection between the switch and the assistive device or system. Field-testing on an infrared wireless link is presently being completed. Along with other possible input methods, such as very thin (<2 cm) tape switches, optical methods are presently being examined. Some of the circuits are being redesigned for incorporating features such as analog output and minimization of the supply current. Some basic studies are also being conducted to better understand the capacitive coupling between an area of the body and a metal plate.

Recent Publications Resulting from This Research

Design of Electronic Devices to Aid Handicapped Children.
Williams P, Saha S, in Proceedings of the Eighth Southern Biomedical Engineering Conference, 5-8, 1989.

[250] Switchless Selection Techniques Using a Headpointing Device

Gil Hamann, BAsC; Morris Milner, PhD, PEng; Henry O'Beirne, MA, MASc; Fraser Shein, MEng, PEng
Hugh MacMillan Rehabilitation Centre, Toronto, Ontario M4G 1R8 Canada

Sponsor: *Natural Sciences and Engineering Research Council of Canada; University of Toronto*

Purpose—Our purpose was to investigate the use of simple head gestures to emulate the standard mouse buttons in a graphical user interface. Current graphical user interfaces often require selecting a character or a file by clicking a mouse button once. Double clicks are used to select a word or to start an application. Highlighting a phrase or moving a file is done by pushing and holding the mouse button while moving the mouse to the new position. This type of interface presents a barrier to many people with disabilities.

Specific objectives included: 1) demonstrating several gestural techniques for simulating mouse button selection methods without using external switches; 2) evaluating the techniques implemented and describing their advantages and disadvantages; and, 3) developing strategies and criteria for customizing the parameters of the different techniques in order to achieve good user performance and satisfaction.

Progress—People with good head control can use a headpointing device to emulate a mouse and move a

cursor about the screen. In order to make mouse button selections, external switches such as sip-and-puff or eyebrow switches can be used, but this is not an ideal solution. By using head gestures, it is possible to implement switchless selection methods. The measurable parameters of head gestures include pause time and the direction, duration, speed, and distance of movement. Combinations of these can be used to differentiate between intended selections.

The Long Range Optical Pointer (LROP), a headpointing input device originally developed at the Trace Research and Development Center, was modified to allow its use with a high resolution graphics display. Two switchless selection techniques were then developed using the modified LROP. These are the Multi-Level Pause technique and the Nod and Shake technique.

With the Multi-Level Pause technique, the user holds the pointer steady over the intended target to begin the selection. An initial pause causes a single mouse-button-down action to be simulated. This allows the user to drag the selected object. Pausing longer causes the mouse

button to be released, simulating a single click. A further pause simulates a double click. The dragging action can be over-ridden by the user with a separate configuration program.

The Nod and Shake technique also begins with an initial pause; however, with this technique a cursor clutch is set, causing the cursor to freeze on the display. The user can then nod in one of three directions to simulate a single left-button click, a double left-button click, or a single right-button click. To start the dragging action, the person can simply pause longer instead of nodding, similar to the Multi-Level Pause technique.

Preliminary Results/Future Plans—The two techniques have been used to control a commercially available paint-

ing program which requires the use of all of the mouse button actions described. The clients who have used the techniques have found them to be effective and useful.

Some training is necessary in order to use the Nod and Shake technique consistently. To facilitate this, a small training utility will be developed. Good feedback is required for the user to know what state the system is in. Since the current clicks and beeps can become confusing, a more interesting range of audio cues will be created.

Recent Publications Resulting from This Research

Two Switchless Selection Techniques Using a Headpointing Device for Graphical User Interfaces. Hamann G, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 439-440, 1990.

[251] Gestural Predictive Control Systems for Persons with Motor Impairments

Tom Nantais, BASc; Morris Milner, PhD, PEng, CCE; Henry O'Beirne, MA, MASc; Fraser Shein, MEng, PEng
Hugh MacMillan Rehabilitation Centre, Toronto, Ontario M4G 1R8 Canada

Sponsor: *Natural Sciences and Engineering Research Council of Canada*

Purpose—The letter board is a well-established means of communication between a person with motor impairment and another person. The motor impairments of a letter board user usually affect the ability to speak and write; however, communication with the letter board can be efficient and flexible. One common observation is that the experience of the listener in communicating with a given individual has a positive influence on the communication rate. The experienced listener appears to be able to employ information about the user (not available to the inexperienced listener), in order to make predictions regarding the user's destination on the letter board. A device which could play the role of that experienced listener could provide improved interpretive power to an inexperienced listener. In fact, such a device could possibly improve communication between the user and the most desperately inexperienced listener of all: the modern computer.

A system capable of gaining and using experience about the communicative qualities of a particular letter board user is to be developed and tested. Specifically, the system's ability to predict the user's next word from characteristics of motions across a letter board is to be the measure of its success.

Methodology—There are two main questions in need of answers before the objective can be reached: 1) How does

the experienced listener make predictions about the next character to be selected? That is, on what qualities of the process must the system gain experience to be able to make reliable predictions? and, 2) How can an electronic system be made capable of gaining experience about anything?

A study called "The Role of the Experienced Listener in Augmentative Communication Systems (RELACS)" is currently being conducted in the Motor Functions Laboratory. The purpose of the study is to determine what constitutes "experience" in communicating with a letter board user.

Messages for the user to communicate to the listener are shown to the user through a computer monitor behind the listener's head. A marker-based hand tracking system quantitatively records all of the user's hand motions for later analysis. The entire session is videotaped so that the listener can later give reasons for any predictions that were made during the communication process.

Progress—In response to the question of how a computer can be made capable of learning about the communication qualities of each user it encounters (which are expected to be widely different), the design of neural networks is being explored. The neural network is a development in artificial intelligence which has recently become capable of solving "real-world" problems in pattern recognition.

Implications—This is a very active and exciting area of research, and it is considered that the neural network has the potential to revolutionize computer access

for people with physical disabilities by providing the computer with the ability to learn about each situation in which it is placed.

[252] Mobility Training and Evaluation for the Home and School Environment

Sheila Jarvis, BSc, PT; Stephen Naumann, PhD, PEng; Geb Verburg, MA
The Hugh MacMillan Rehabilitation Centre, Toronto, Ontario M4G 1R8 Canada

Sponsor: Ontario Mental Health Foundation; Toshiba of Canada Ltd.

Purpose—Physically disabled persons who are cognitively delayed to the extent that they cannot use assistive devices because they do not understand the functions of switches are at a serious disadvantage. Their inability to control devices prevents them from benefitting directly from mobility or communication devices, and also reduces their opportunities to learn from the experiences that these devices afford. In an attempt to remediate this problem, a community (home or school) training program using switches and toys was designed for persons who are developmentally delayed.

Methodology—Students who are both physically and cognitively impaired, and their parents or teachers, are given a trainer unit, a Toshiba T1000 microcomputer, lap tray, and five toys to use at home or at school. The trainer unit and program are being evaluated with 16 subjects, ranging in age from 5 years 1 month to 20 years 6 months, with a mean age of 11.5 years (standard deviation 5.4). Intelligence levels are in the severe to profound retardation range. The evaluation uses a pre-post experimental design that also allows for the comparison of subjects against controls, and against their own pre-study clinic records.

Each subject receives a tray with five embedded switches, each with its own stimulus lights mounted adjacent to the switch. At the start of the training program, only one switch is exposed, and only one toy is connected. When the student completes 100 trials in either parent/teacher-guided or free-play sessions, he graduates to the next training step. In the second step, a second switch is uncovered and incorporated into the training program. Another 100 trials later the student graduates to Training Step 3, at which time the third switch is uncovered, allowing three toys to operate successively. A total of five steps are being used.

In order to help the students make the connection between making toys move and making one's wheelchair move, an intermediary step was introduced in which the participants used training trays and switches to control the movement of a powered wheelchair. The wheelchair-mounted training trays have five variable-position pressure switches with attached stimulus lights, and a remote switching box that allows the therapist to control the stimulus lights and switches on the tray individually. The switching device was designed so that only one switch could be active at a time. This tray is useful for generalization training sessions.

A communications program (PROCOMM) is used to review the progress of the client and change the program—via the modem—to the next training step. Data collected at home or school are downloaded to the Centre and analyzed to determine if the subjects are ready to move on to the next training stage.

Results—With the exception of six subjects, all subjects were on the Centre's active caseload and had been referred for a mobility assessment from 6 to 18 months prior to the start of the study. At the start of the study, subjects who were assessed 18 months ago were still not able to drive a wheelchair.

With 2 subjects withdrawn for medical reasons (surgery), 7 out of 14 subjects show improvement in their wheelchair driving performance. If the subjects continue to progress towards behavior reflected in mobility skills, it is expected that by month 12 at least one person will be ready for a prescription, and two will need several weeks of in-chair training before receiving their own chair. Another three or four will have reached the point of having mastered directional switches and will have learned how and when to stop. This amount of change for subjects who have shown virtually no progression for years is extremely encouraging.

Recent Publications Resulting from This Research

A Microcomputer-Aided Mobility Training Program for the Multiply Handicapped. Zanier D, McPhail P, Voelker S, Ment Retard Learn Disabil Bull 17(1):51-62, 1989.

A Training and Evaluation Tool for Remedial Cause and Effect Development. Snell E et al., in Proceedings of the 12th Annual RESNA Conference, New Orleans, 43-44, 1989.

[253] Guidelines for the Requirements of Computer-Based Systems to Accommodate Direct Manipulation as a Means of Alternate Access

Morris Milner, PhD, PEng; Penny Parnes, BSc; Stephen Naumann, PhD, PEng; Fraser Shein, MEng, PEng; Nicholas Brownlow, BA; Jutta Treviranus, BSc, OT
Hugh MacMillan Rehabilitation Centre, Toronto, Ontario M4G 1R8 Canada

Sponsor: Ontario Ministry of Colleges and Universities; IBM Corporation; IBM Canada Ltd.

Purpose—The goal of this project was to determine appropriate alternative access techniques for computer control by severely physically disabled people in a direct manipulation environment. Instead of typing commands, the user indicates objects (icons, text, menus, and graphical objects) depicted on the screen and directly manipulates them with a pointing device such as a mouse.

Specific research objectives were to: 1) describe the problems that people with physical disabilities have within a direct manipulation environment; 2) propose and describe modifications to pointing devices and to the environment to improve accessibility; and, 3) to make recommendations for future systems that will support the techniques or modifications that are proposed.

Methodology—Most of the problems posed by direct manipulation relate to the physical demands of the pointing device. The use of a pointing device involves several physical tasks: moving the pointing device, clicking one or more buttons, dragging the pointing device while holding the button, and moving between the keyboard and pointing device. The user must therefore be able to move the pointing device with relatively fine continuous control and press the button, as well as do both at the same time.

Progress—Much of the first year of the project was devoted to gaining a deeper understanding of the significance of direct manipulation, defining problems that can occur with pointing devices, and developing software to test various skills related to manipulating objects on the computer screen. In the second year, specific modifications to several pointing devices were proposed and implemented. These were developed in an iterative process of clinical assessment, device modification, and objective evaluation within clinical trials involving seven

individuals with physical disabilities. These trials spread across approximately 20 sessions, each lasting 2 hours, in which modifications were made to refine the participants' use of various pointing devices. Four other persons participated in further trials in which alternative direct manipulation techniques for accessing a text editor were tested using a single switch as a means of input to the computer.

Results—Our investigation identified key problems associated with pointing devices, and we were able to address many of them. All participants in our investigation were able to perform direct manipulation tasks using some pointing device. Most of the necessary modifications were relatively superficial and easily achieved. In some instances, prototype developments were required to achieve some functions. Dragging was the most difficult of all direct manipulation operations. The most glaring problem, and one that was not resolved within this study, was the movement between a physical keyboard and a pointing device. This problem alone decreases the benefits of direct manipulation interface in applications that involve keyboard entry.

One idea under development is to allow users with severe physical disabilities to delegate tasks by selecting intelligent objects/processes in the computer which will carry out certain functions. Selection may be done with as little as a single switch and a scanning technique.

Recommended strategies for developers of future systems have been prepared, based upon the experience gained within the trials. Some are feasible with current graphical user interfaces, but many would require changes in the interface design. Implementation of even the most modest strategies would open up access to new groups of users.

Future Plans—Two new research projects have been initiated from this work. The first investigates the combined use of a head pointing input system and voice recognition as alternate input for direct manipulation. The second studies the integration of voice recognition and scanning alternate access systems.

Recent Publications Resulting from This Research

Direct Manipulation: Its Significance for People with Disabilities. Brownlow ND et al., in Proceedings of the 12th Annual RESNA Conference, New Orleans, LA, 244-245, 1989.
Direct Manipulation: Problems with Pointing Devices. Brownlow ND et al., in Proceedings of the 12th Annual RESNA Conference, New Orleans, LA, 246-247, 1989.

Accessible Graphical User Interfaces: Strategies for Developers. Brownlow ND et al., Toronto: Hugh MacMillan Rehabilitation Centre, 1990.

Direct Manipulation of Text by Scanning. Shein GF et al., in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 147-148, 1990.

Don't Manipulate, Delegate! Brownlow ND et al., in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 153-154, 1990.

Modification of Direct Manipulation Pointing Devices. Treviranus J et al., in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 151-152, 1990.

A Software Environment for the Testing of Pointing Ability. Brownlow ND et al., in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 149-150, 1990.

Pointing Devices for Direct Manipulation: Problems and Solutions. Treviranus J et al., J Assist Technol (in press).

[254] Development of a Light Pointer

Louis Goudreau, BASc, PEng; Gordon Evans, CET

Department of Rehabilitation Engineering, The Rehabilitation Centre, Ottawa, Ontario K1H 8M2 Canada

Sponsor: *The Rehabilitation Centre, Ottawa*

Purpose—Light pointers are used as a communication aid and to activate light-sensitive switches. A lightweight and energy-efficient model was designed. Research is ongoing to increase the useful range of the light beam.

Progress—The shell of a mini Mag Lite flashlight was redesigned. Lenses were added and the light bulb

was replaced with a high-intensity light-emitting diode. Batteries were put in a compartment that can be carried in a pocket. The light pointer weighs approximately 25 g and the useful range of the red beam is about 1.5 m. A new model is under development to increase its range.

[255] Extraordinary Computer/Human Operation

G. Filz; H. Peddie; J.L. Arnott; A.Y. Cairns; A.F. Newell

Microcomputer Centre, University of Dundee, Dundee DD1 4HN Scotland

Sponsor: *Science and Engineering Research Council*

Purpose—The aim of this research project is to develop an accessible office workstation for a disabled user. This includes investigating the various types of input and output devices that are currently available and can be used by a disabled user, and incorporating a selection of these in a workstation application, thereby increasing the bandwidth available to each user.

Features such as monitoring, inferencing, and prediction will be implemented into the system to improve the interaction between the disabled user and the application.

This research is being carried out in collaboration with an avionics company involved with the human/computer interaction problems faced by pilots in modern

aircraft, in the hope that there will be shared ideas and resources.

Progress—This project is still in its early stages. The progress so far has been to research and collect information on input and output devices currently available. Information is also being collected on knowledge base systems to investigate how features such as monitoring, inferencing, and prediction can be implemented.

Future Plans—Future plans are to develop a prototype of a high quality computer-based workstation which incorporates all of the above features.

[256] Development of a Voice Output Intelligent Communication Enhancement System (VOICES)

Peter A. Reich, PhD; Pauline H. Parnes, BSc, DSPA; Anne Warrick, MPhil; Jutta Treviranus, BSc(OT); Fraser Shein, MEng, PEng

Department of Linguistics, University of Toronto, Toronto, Ontario M5S 1A1 Canada; The Hugh MacMillan Rehabilitation Centre, Toronto, Ontario M4G 1R8 Canada

Sponsor: *Social Sciences and Humanities Research Council of Canada*

Purpose—The purpose of this project is to design a communication aid which can use linguistic and semantic information to make intelligent guesses as to what the communicator intends to say, thus reducing the number of key activations necessary to produce grammatically correct speech.

Methodology—The project proposes a system (rather than a particular device) for creating communication aids tailored to each individual user. The main component of such a system is an inventory of about 3,000 symbols, each equipped with vocabulary items, and their associated grammar. The user, and people working with the user, will be given tools from the inventory provided,

which will make it easy to construct and modify the device to suit the user.

The system will be programmed on Macintosh computers in HyperCard. The portable Macintosh will be used since it is battery-powered and can be mounted on wheelchairs. The symbols that will be used are Blissymbols, which are efficiently stored, displayed, and printed on Macintosh computers by means of the BlissTemplate Font, a Macintosh font developed by Dr. Reich.

Future Plans—The first year of the project will be focused on creating the system, and the second year on testing with users, evaluating its use, and making modifications in light of what is learned.

[257] Modeling of Performance with Computer Access and Alternative Communication Systems

Heidi M. Horstmann, MS; Simon P. Levine, PhD

University of Michigan, Rehabilitation Engineering Program, Ann Arbor, MI 48109-0032

Sponsor: *University of Michigan Rehabilitation Engineering Program; University of Michigan Bioengineering Program*

Purpose—This project explores the application of engineering modeling techniques to improve understanding of the user interface of augmentative communication and computer access systems. The goal of this work is to provide both developers and clinicians with a framework that can improve the development and delivery of alternative access systems. The long-term goal is to use the model to quantitatively predict user performance with these systems and simulate a large range of user and system characteristics. The modeling process also offers a valuable qualitative analysis, since it provides the opportunity to carefully analyze the interaction between the user and an alternative access system, under a wide range of conditions.

Progress—One modeling technique used extensively in the field of human-computer interaction, called the GOMS model (Goals, Operators, Methods, Selection

Rules), has been used for preliminary work. The model provides a comprehensive description of user performance based on system-specific parameters as well as the cognitive, perceptual, and motor capabilities of the user. The GOMS technique has been used to model three row/column letter scanning interfaces, two with some form of word prediction and one without, to gain a more rigorous understanding of how word prediction affects a user's performance.

Several software tools have been developed that will make it possible to perform model validation studies. These include: 1) a fully programmable word prediction module, to allow simulation of numerous existing word prediction techniques; 2) a stand-alone data collection utility that records the time and content of a user selection from either the word prediction module or any other RAM-resident keyboard emulation interface; and, 3) statistics utilities that generate a profile of the user's

performance using the raw data from the data collection utility, as well as information about the word prediction dictionary contents.

Preliminary Results—Preliminary results, based on model simulations for the three interfaces considered, suggest the possibility that word prediction interfaces, developed as a faster alternative to row/column letter scanning, may actually be less efficient than letter scanning in some situations.

In addition, preliminary model validation work has been performed in the clinical setting. Performance data for a single user of a row/column letter scanning system was collected over a period of two months and compared to theoretical predictions of performance based on a simple model of row/column scanning. The data agreed closely with the model predictions over a wide range of scanning timing parameters, providing support for the quantitative accuracy of the modeling technique.

Future Plans—A primary direction for future research is to collect data on the performance of subjects with a variety of alternative access methods (including word prediction systems), and compare it with the model predictions that have been developed. A number of modeling techniques, including the GOMS model, will be studied to determine those most suited to this application. Refinement of model descriptions and input parameters can then be made to improve model accuracy.

Recent Publications Resulting from This Research

- Modeling of User Performance with Computer Access and Augmentative Communication Systems for Handicapped People. Horstmann HM, Levine SP, in Proceedings of the 11th Annual Meeting of the Cognitive Science Society, Ann Arbor, MI, 659-666, 1989.
- Quantitative Modeling in Augmentative Communication—A Case Study. Horstmann HM, Levine SP, in Proceedings of the 13th Annual RESNA Conference, Washington, DC, 9-10, 1990.
- Modeling of User Performance with Computer Access and Augmentative Communication Systems for Handicapped People. Horstmann HM, Levine SP, *Augment Alternat Commun* (in press).

D. Private and Public Programs

[258] Using Existing Databases to Analyze the Medicaid Personal Care Optional Benefit Service

Simi Litvak, PhD; Jae Kennedy, MA
World Institute on Disability, Oakland, CA 94606

Sponsor: *U.S. Department of Health and Human Services*

Purpose—The goal of this project is to describe how the various states have designed personal assistance service (PAS) programs using funds under the Medicaid personal care services option (pc-option).

The specific objectives of this project are to: 1) provide a national aggregate overview and a state-by-state profile of all the Medicaid pc-option programs as of 1985 and 1989; 2) discern trends in the way states have used the pc-option from 1985-1989; 3) compare the similarities and differences between pc-option programs in the different states; 4) compare on an aggregate level the similarities and differences between the Medicaid pc-option programs and programs funded by the Medicaid Waiver, Title XX, Title III, state funds, and mixtures of federal funds; 5) ascertain the degree of flexibility states have had in designing their programs within the limits imposed by Section 42 CFR 440.170(f); and 6) “understand the factors that

influenced states’ policy choices with regard to program design and implementation—including decisions about participation, program size, target groups, definition of services, organization of service delivery system, etc.”

Methodology—The World Institute on Disability (WID) built on its 1985 survey of the universe of PAS programs in the U.S. by conducting a follow-up mail survey of previously interviewed programs as well as new ones. The 1985 data set and the new 1989 data set are being analyzed in order to compare programs by funding source. In addition, WID is conducting site visits to six states in order to address the knowledge gaps identified from the analysis of the quantitative data.

Preliminary Results—Results of the research are now being examined. They will include the following reports:

1) a descriptive profile of each pc-option program from 1984 and 1988 data; 2) an aggregate analysis of the pc-option programs; 3) a comparison of the pc-option aggregate profile to the profiles of programs funded by other funding streams; and, 4) reports of site visits.

Future Plans/Implications—The major outcome of this research will be to provide policymakers and planners on the national and state levels with the quality of informa-

tion needed to develop a comprehensive and effective PAS system. More specifically, this research will allow policymakers to gain a better understanding of how funding source mandates, along with state creativity, have shaped the various ways in which services are delivered.

Recent Publications Resulting from This Research

The Effect of Government Funding Source on Personal Assistance Programs: A Summary of 1985 National Survey Data. Litvak S, Kennedy J. Oakland: World Institute on Disability, 1990.

[259] Applicable Barrier-Free Concepts Adaptable to Modern Technology Developments

Dieter P. Philippen, MSc, BSc, Dipl Ing; Lothar Marx

Institute T.L.P.e.V., Rehabilitation Research and Development, D-5580 Traben-Trarbach, Germany

Sponsor: Federal Ministry for Regional Planning, Building, and Urban Development

Purpose—Following the concept of a barrier-free society, the question was raised as to what extent modern technology can be adapted to support individual independence by evaluating functional application based on a human factor containing all ages, abilities, and disabilities.

This research, which will be finalized by March 1991, evaluates applicable modern technologies in various fields for use in barrier-free environments in order to improve independent living for the elderly and persons with disabilities.

This international investigation was launched to find solutions to improve integration and find alternatives to institutional care for the elderly, support research in the field of gerontology, and provide assistance for the development of independent living rehabilitation for the elderly.

At the same time, the investigation should suggest the level of acceptance for high-tech application by the elderly in the living environment and find ways and means to educate them with the goal of extended independence supported by modern technology.

Another major goal is the utilization of any type of modern construction and/or material technology to create barrier-free housing and urban development for all

people at comparable cost; buildings and environments which compensate for restrictions of age and disabilities, and are freely accessible at all levels, or are constructed with provisions for added improvements if needed.

This conceptional development is supported by a federally funded research and development program under the heading, "Age-Complimentary-Technology," meaning to support developments which are capable of increasing the self-sustained independent status of all people of all ages in their individual environment versus integration into institutional homes of any kind.

Progress—The investigators make use of all available data and information systems and have launched an extensive international mailing to various applicable industries, requesting product literature, which is being reviewed in detail. Suggested usable items or developments within the boundaries of this research are recorded, including pertinent pictures. Approximately 15,000 letters have been mailed.

Future Plans—The results will be discussed and conclusions offered. The final report will be published this summer.

[260] Development of a Collaborative Training and Job Placement Program in Computer-Aided Drafting

David M. Horowitz, SM; Marilyn Lash, MSW; Vincent Licenziato, BA

Rehabilitation Engineering Program, Department of Rehabilitation Medicine, Tufts University School of Medicine, New England Medical Center, Boston, MA 02111

Sponsor: Massachusetts Rehabilitation Commission

Purpose—Many individuals with severe disabilities possess the proper motivation and abilities to pursue gainful careers in engineering-related fields. Nevertheless, these vocational areas have been closed to individuals with severe disabilities. This program will research methods by which individuals with severe disabilities can achieve gainful employment. A comprehensive supported training and employment program in Computer-Aided Drafting (CAD) will include the identification and implementation of appropriate computer adaptations to allow individuals with severe disabilities access to a computer. A training curriculum will provide individuals with computer literacy and expertise in the operation of CAD software. Collaboration with state agencies will allow for the identification and involvement of affirmative action employers. It is anticipated that a vocational rehabilitation

model incorporating a career internship will result in gainful employment.

Progress—Eleven individuals referred to the Rehabilitation Engineering Program were evaluated, and four individuals were enrolled in the CAD training program. The CAD training is being conducted at Roxbury Community College, Boston, where these individuals have been integrated into the regular classroom activities. Social work services are provided to help both able-bodied and disabled students work together.

Implications—It is anticipated that the program will serve as a model for the integration of advanced rehabilitation services provided by tertiary care centers into long-term community-based vocational training programs.

[261] Development of a Parts Counter for Persons with Mental Retardation

John H. Leslie Jr., PhD; Mark Graffe

Cerebral Palsy Research Foundation of Kansas, Wichita, KS 67208

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—The Wichita REC is a consortium of The Cerebral Palsy Research Foundation of Kansas (CPR) and The Wichita State University College of Engineering (WSU). It is mandated by its funding agency, the National Institute on Disability and Rehabilitation Research (NIDRR), with the enhancement of the vocational opportunities of persons with severe disabilities.

During 1986, the state of Kansas designated CPR as the sole rehabilitation engineering support entity for its Supported Employment Initiative program. Since that time, CPR staff have fabricated numerous assistive devices for work centers and businesses that employ people with cognitive disabilities.

CPR was approached in 1989 by a center in north-eastern Kansas that had two clients employed in a counting and packaging operation. Counting and packaging parts is a common employment activity for persons with

cognitive disabilities. For most of these workers, this is a slow process with a high error rate. Unfortunately, many counting fixtures are very specific relative to the size and shape of a particular product and are, therefore, not very versatile. Counting scales calibrated for various-sized parts are available, but are expensive and difficult for persons with cognitive disabilities to operate.

Results—A parts counter has been designed that incorporates the following design criteria: 1) it was required to count parts that ranged in size from 1/8 inch to 1/2 inch in diameter; 2) it was required to count quantities ranging from 4 to 135; and, 3) the device had to be easy to understand and operate.

The concept of the counter is simple. Operators drop parts, one at a time, into a funnel which guides the parts between a pair of optical sensors, triggering a counting

circuit. The funnel gives the operator a large target to hit, enabling persons with poor eye-hand coordination to operate the counter. To allow for different size parts, the hole in the funnel was made large enough to accommodate the largest part. Funnel inserts were then made with smaller holes for smaller parts. Use of inserts ensure that the parts drop through the center of the optical beam.

To comply with the criteria of varying count quantities and simple operation, it was decided to use a comparator circuit in which the operator would enter the desired count on three thumbwheel switches. As parts drop through the funnel, the circuit compares the running count with the total count. When the number of parts equals the count on the switches, a red light is turned on. A reset button is used to reset the internal count to zero and turn off the red light. The process is then repeated,

or a new count is set. A yellow light was added to the circuit to indicate when the count was three less than the total, warning the operator to proceed slowly and watch for the red light.

One option considered was to use a tally counter that would increase as each part was dropped through the funnel. However, this requires a worker with a better understanding of numbers to keep a close watch on the count. It was decided that lights were more effective in increasing the vigilance of the operator. Another option would be a buzzer, for persons who are visually impaired.

When the parts counter was installed, there was a tendency to drop more than one part through the counter at a time. It was eliminated through training. Otherwise, cognitively disabled workers had no difficulty utilizing the counter.

[262] Rehabilitation Engineering Center on Service Delivery Models

Anthony J. Langton; Lawrence H. Trachtman; Ronald W. Parker

Center for Rehabilitation Technology Services, South Carolina Vocational Rehabilitation Department, West Columbia, SC 29171-0015

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—The Center for Rehabilitation Technology Services (CRTS) is a rehabilitation engineering center (REC) supported by the National Institute on Disability and Rehabilitation Research (NIDRR), and operated as part of the South Carolina Vocational Rehabilitation Department. Under a cooperative agreement with NIDRR, the mission of the center is to demonstrate and disseminate innovative models for the delivery of cost-effective rehabilitation engineering services to assist in meeting the needs of, and addressing the barriers confronted by, individuals with disabilities. Within this broad mandate, the following scope of work has defined the parameters for CRTS' activities: 1) develop and test models of assistive technology service delivery systems; 2) evaluate the effectiveness of these models; 3) develop a model of statewide databases; 4) establish continuing education programs to provide accessible training; and, 5) develop and test training programs specifically designed to train volunteer technology counselors nationally. Through publications, presentations, and involvement in national initiatives, CRTS shares the results of its activities with individuals and organizations in the Southeast and across the United States.

Progress—CRTS has initiated a number of projects designed to address the above scope of work. The following is a list of current project titles: 1) Development of an Assistive Technology Information Resource Center (IRC); 2) Access Technology—Development of a Statewide Information and Referral (I&R) Service for Assistive Technology Applications; 3) Development of an Assistive Technology Demonstration Center (TDC); 4) Development of a Guide to Funding Resources for Assistive Technology in South Carolina; 5) Implementation of Regional Service Areas for Statewide Technology Access; 6) Development of a Primer of Assistive Technology Terminology; 7) The Utilization of a Facsimile Machine in Service Delivery: A Pilot Project; 8) A Survey of Rehabilitation Engineers Nationwide; 9) Symposium Series on Critical Issues Affecting Assistive Technology Services; 10) Utilization of Assistive Technology in the Vocational Evaluation Process; 11) Development of a Service Provider Directory; 12) Development of Planning Guides for Implementing Assistive Technology Services; and, 13) Training Materials for Assistive Technology Awareness.

Future Plans/Implications—The center is continuing to address critical issues affecting the distribution and

utilization of technology by persons with disabilities. Among the core areas of focus in upcoming activities are coding strategies and alternative methods of funding for assistive technology, information dissemination, training and qualifications of service providers, models of community service delivery, volunteer technology delivery, rural service delivery, universally designed products, and

technology and transition. CRTS welcomes input by persons and organizations nationwide on these and other service delivery issues.

The reader is encouraged to contact the center for more information on specific activities and for publication information.

[263] Operational Definition of Independence

Margaret A. Nosek, PhD; Marcus J. Fuhrer, PhD

ILRU Research and Training Center on Independent Living at The Institute for Rehabilitation and Research; Department of Physical Medicine and Rehabilitation, and Department of Psychiatry, Baylor College of Medicine, Houston, TX 77030

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—This project is designed to develop an operational definition of independence that incorporates three dimensions of the term: perceptions of control over one's life, psychological factors, and behavioral or functional characteristics. The objective is to develop an assessment instrument to quantify an individual's independence in each of the above domains.

Progress—After extensive search of the literature and expert consultation, the Personal Independence Profile (PIP) was constructed to operationalize the consensus definition. The PIP consists of items measuring perceived control over one's life, selected from Flanagan's Quality of Life Domains; items from Fordyce's Independence Scale, which deals with psychological factors such as competitiveness, self-esteem, and group autonomy; and sections from the Arthritis Impact Measurement Scale (AIMS), a Guttman-type ordering of general functional ability items.

The next step in the development of the PIP was to conduct various tests of its validity. Two hundred subjects in 10 centers for independent living (CIL) across the country were sent the PIP, 120 of whom also completed questionnaires designed to measure the same or similar constructs to test the convergent validity of the PIP. In addition, CIL staff who knew the subjects well rated each person on a global rating scale. A sample of 185 of these 200 subjects produced data that were complete enough to enable cluster analysis of the PIP-Psychological Independence, PIP-Control, and PIP-Physical Independence scores.

Results—Responses from the initial 61 subjects surveyed were analyzed to test a model proposing that indepen-

dence of living arrangements, productivity, participation in leisure activities, and mobility would be antecedents of perceived control of an individual's life spheres, as well as that the severity of an individual's physical disability and level of income would directly affect these antecedents of control. Educational level was found to interact with living arrangements, productivity, and leisure activities to predict perceived control. Mobility, however, directly predicted degree of perceived control. The conventional wisdom that an interaction between physical ability and income would predict each antecedent of control was not supported. In future studies, other variables possibly affecting these antecedents, such as psychological self-sufficiency, will be explored.

Validity testing of the PIP resulted in Cronbach's alpha coefficients of 0.79 for psychological independence, 0.86 for control, and a range from 0.66 to 0.94 on the five subscales of the functional (AIMS) section. These results support the internal validity of all three constructs of the PIP. Reliability estimates of the five parts of the AIMS yielded coefficients of reproducibility from 0.87 to 0.93.

Cluster analysis of the three PIP scales from 185 subjects using Ward's minimum variance procedure yielded three salient clusters: 1) 81 subjects were identified as independently minded and relatively nondisabled; 2) 55 as nonindependently minded; and, 3) 49 as independently minded and relatively disabled. The first cluster demonstrated relatively average levels of psychological independence, tended to feel in control of things important to them, and had a relatively good physical status. The second cluster had relatively low levels of control over their lives and were unable or unwilling to take the initiative to make changes, but exhibited no common factors for physical independence. The third cluster exhibited

relatively high levels of psychological independence and control, but a high degree of physical impairment. This

last group was similar to the first group except for having more severe physical impairments.

[264] Evolution of Independent Living Programs: A Longitudinal Study

Margaret A. Nosek, PhD; Laurel Richards; Laurie Gerken

ILRU Research and Training Center on Independent Living at The Institute for Rehabilitation and Research; Department of Physical Medicine and Rehabilitation, Baylor College of Medicine, Houston, TX 77030

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—The purpose of this project is to maintain a database on the status of independent living programs (ILPs) nationally, and to identify trends in the development of ILPs, the emergence of issues encountered in the delivery of independent living services, and changes in the characteristics of consumers of these services.

Progress—Profiles of each program responding to a full-length survey have been published in the *ILRU Registry of ILPs*. In late 1988, a revised and updated survey instrument was mailed to over 400 programs listed in the *ILRU Directory of Independent Living Programs*. Information was solicited concerning populations served, services provided, characteristics of persons providing services, methods by which services are provided and programs administered, sources of funding, and relationships between programs and their communities. Responses from 189 programs were received and analyzed. A manuscript describing the evolution of independent living programs in America and comparing 1988 with 1986 results has been submitted for publication.

Results—A comparison of the 1986 and 1988 results has revealed some promising trends. Significant improvements have been made in both the volume and quality of service delivery; board and staff training; proportions of boards, executive directors, and staff with disabilities; and the size of federal grants. In 1988, more than three-fourths of the programs offered training to the board, and 94.7% offered training to the staff. By contrast, only 6% of the programs reported offering board training and 11% staff training in 1986. People with disabilities now occupy a majority of executive director, administrative, and staff positions, compared to filling less than half of these positions in 1986. In 1986, only 51% of programs receiving Title VII funds complied with National Council on

Disability (NCD) standards for the involvement of persons with disabilities in direction, management, and service delivery. Compliance had risen to 82.6% by 1988, and unlike 1986 findings, there was a significant relationship ($p < 0.05$) between compliance and both the receipt of funds and the amount of funding received. Complying programs offered significantly more services and served significantly more persons than did noncomplying programs. These findings have strong implications for federal policy and funding in the independent living area.

Additional analyses were done to determine the impact of program age, consumer control, and budget size on the operation of independent living programs. Results reflected the wide diversity of program characteristics. Older programs tended to have more diverse funding. Programs with higher levels of consumer control tended to have more staff with disabilities, engaged in more advocacy activities, and participated more in networks. Programs with larger budgets were more likely to offer residential housing services and were less active in advocacy and awareness activities.

Future Plans—The *Directory of Independent Living Programs* is updated and reissued approximately 5 times per year. Research staff will continue to update the *Directory* and respond to specific inquiries with individualized data runs and reports. Analysis will continue on the ILRU National Database on Independent Living Programs, with trends published as they emerge.

Recent Publications Resulting from This Research

Levels of Compliance with Federal Requirements in Independent Living Centers. Nosek MA, Jones SD, Zhu Y, J Rehabil 55(2):31-37, 1989.

Independent Living Programs: The Impact of Program Age, Consumer Control, and Budget on Program Operation. Nosek MA, Roth PL, Zhu Y, J Rehabil 56(4), 1990.

[265] The Definition of "Peer": Consumer Perspectives and Significance in the Delivery of Counseling Services

Margaret A. Nosek, PhD; Marcus J. Fuhrer, PhD; Laurie Gerken; Laurel Richards

ILRU Research and Training Center on Independent Living at The Institute for Rehabilitation and Research; Department of Physical Medicine and Rehabilitation and Department of Psychiatry, Baylor College of Medicine, Houston, TX 77030

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—This project is intended to assess the perceptions of disabled persons regarding the definition of peer and the provision of counseling services by peers. Peer counseling is essential to consumer involvement in independent living programs, as evidenced by the mandatory inclusion of peer counseling in all independent living programs receiving funding under Title VII of the 1978 Amendments.

Progress—The quasi-experimental design of this project focused on perceptions of counselor credibility. The research question asked which factors account for the greater variance in ratings of counselor credibility: disability status of the counselor, whether or not the counselor was professionally trained, or whether or not the content of the interaction was disability-related. Seventy-two subjects completed selected items from the Counselor Effectiveness Rating Scale, after viewing photos of four counselors, reading and hearing biosketches for each, and listening to tape recordings of two consumers describing a problem to a counselor.

Results—The data were analyzed using a double multivariate repeated measures analysis of variance within

subjects factors (Professionalism, Disability, and Vignette content, each with two levels) and five dependent variables (Experience, Expertness, Interest, Understanding, and Ability). Although the three-way interaction among Professionalism, Disability, and Vignette content was not significant, all three multivariate two-way interactions were statistically significant. An important finding of the study is that disability status of counselors significantly affects ratings of counselor credibility. For both professionals and nonprofessionals, disabled counselors received higher mean ratings than did nondisabled counselors on all five measures, although this difference was smaller for professionals. Also, for the disability content interaction, subjects rated disabled counselors more favorably than nondisabled counselors on all five measures.

Recent Publications Resulting from This Research

Perceived Counselor Credibility by Persons with Physical Disability: Influence of Counselor Disability Status, Professional Status, and the Counseling Content. Nosek MA, Fuhrer MJ, Hughes SO, Rehabil Psychol (in press).

[266] Independent Living in Rural Areas: A Longitudinal Study

Margaret A. Nosek, PhD; Laurie Gerken

ILRU Research and Training Center on Independent Living at The Institute for Rehabilitation and Research; Department of Physical Medicine and Rehabilitation, Baylor College of Medicine, Houston, TX 77030

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Under a 3-year grant from NIDRR, ILRU expanded independent living opportunities for disabled residents of rural areas. Five demonstration sites were established and given ongoing support until the project was completed in April 1986. The current Research and Training Center project is designed to examine the long-term effects of these interventions in terms of quality and quantity of ongoing activities and outcomes for the community.

Progress—The first component of this evaluation project involved an initial assessment of two demonstration sites when the ILRU rural demonstration grant was completed. This initial assessment enabled the collection of baseline data to be used for comparison in subsequent years. Follow-up assessments were completed after 18 and 36 months, from 1984 through 1988, in two sites using the Community Needs and Resource Survey as well as personal interviews with people with disabilities, religious

leaders, and media representatives. Results reflect different needs predominant in each community.

Results—Two of the five demonstration sites established independent living centers, while the other three sites pursued other options for service delivery. The in-depth studies of two sites yielded contrasting outcomes. The independent living project in Site I resulted in the establishment of a fully operational center for independent living (CIL). The Site II project had a positive impact on incorporating the independent living philosophy into the service delivery system and increasing the number of accessible public buildings and the number of citations for illegal parking in handicapped spaces, but did not lead to the development of a CIL. From 1984 to 1988, a substantial increase in accessibility in the following areas was realized in Site I: health care, housing, employment, attendant services, information and referral services,

transportation, and public buildings. Personal interviews substantiated data collected by the Community Needs and Resource Survey. Information gathered revealed the importance of several factors in successful establishment of CILs in rural communities: real and perceived needs of persons with disabilities in the community, availability and adequacy of existing resources to meet needs, and availability of people to provide leadership and continuing efforts.

Recent Publications Resulting from This Research

- Delivering Independent Living Services in Rural Communities: Options and Alternatives. Potter CG et al., Rural Spec Educ Q (in press).
- Independent Living Services for Children with Disabilities in Rural Areas. Smith QW et al., Rural Spec Educ Q (in press).
- The Personal Assistance Dilemma for People with Disabilities Living in Rural America. Nosek MA, Rural Spec Educ Q (in press).

[267] Instrumental Social Support as a Buffer of Psychological Stress for Persons with Physical Disabilities

Marcus J. Fuhrer, PhD; Margaret A. Nosek, PhD; Carol Potter, PhD

ILRU Research and Training Center on Independent Living at The Institute for Rehabilitation and Research; Department of Physical Medicine and Rehabilitation, Department of Psychiatry, Baylor College of Medicine, Houston, TX 77030

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—A primary purpose of this investigation is to understand some of the principal determinants of psychological stress in people with physical disabilities. The research model underlying this project is based on the well-documented finding that social support can buffer the negative effects of stressors. According to Schaeffer, Coyne, and Lazarus, social support may take the form of instrumental support (e.g., direct assistance with tasks). For people in the general population, most studies have found that emotional or cognitive support is more important than instrumental support in buffering stress. People with severe physical disabilities, however, face distinctive stressors involving task demands of daily living (e.g., dressing, personal hygiene, preparing meals, shopping, and mobility throughout the community). Therefore, assistance with daily life activities comprises an important form of instrumental social support for people with severe physical disabilities. This study is designed to test the hypothesis that instrumental social support, specifically, personal assistance with activities of daily living, is a key factor in determining the degree to which physically disabled people experience stress and psychological

dysphoria. Also examined is whether the life satisfaction of disabled persons is related to severity of disability and satisfaction with social support provided by personal assistants.

Progress—Staff in eight centers for independent living in Federal Region VI recruited subjects for the study and distributed questionnaire packets. Upon receipt of completed surveys, the researchers interviewed subjects by telephone concerning their levels of social support. Approximately 81% of subjects returned surveys and participated in telephone interviews. A sample of 49 respondents used personal assistants. Data analysis is complete, and a manuscript presenting the results is in progress.

Results—Individuals with relatively severe physical disability and more unsatisfactory personal assistance were found to exhibit particularly high levels of perceived stress and psychological dysphoria. A moderately negative relationship was found between perceived satisfactoriness of personal assistance and extent of self-assessed stress and psychological dysphoria in persons with

physical disability ($p < 0.05$). The extent of self-assessed stress and dysphoria, however, had little or no relationship to severity of physical disability. These findings

suggest that satisfaction with personal assistance positively impacts life satisfaction, an effect that is relatively stable across disability levels.

[268] Development of an Instrument to Measure Adequacy of Personal Assistance Services

Margaret A. Nosek, PhD; Marcus J. Fuhrer, PhD; Carol G. Potter, RhD

Independent Living Research Utilization; Department of Physical Medicine and Department of Psychiatry, Baylor College of Medicine, Houston, TX 77030

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—This series of studies is designed to develop and test an instrument for assessing the adequacy of various systems for delivering personal assistance services to persons with diverse severe physical disabilities, their satisfaction with these services, and the effects of personal assistance on employability and health.

Progress—Summaries of more than 150 publications related to personal assistance were compiled and published in 1988. Since then, a literature-based list of personal assistance program components and characteristics relevant to adequacy has been generated and validated by expert review and field testing. During the process of developing adequacy criteria and indicators, it has been necessary to distinguish between assessment and adequacy from a consumer perspective versus a formal program review. Since methodologies for administrative evaluation of programs are abundant and consumer-focused adequacy criteria scarce, development

proceeded from a consumer perspective. It was also necessary to identify distinctions between adequacy and consumer satisfaction and incorporate satisfaction criteria into the instrument. After finalization of criteria and categorization of items by topic, operationalized indicators were developed. The resulting working draft of the instrument—the Personal Assistance Satisfaction Index—has been used in several studies to evaluate model personal assistance services and to assess the role of personal assistance in the health and employability of people with severe disabilities. Statistical analysis to determine the internal validity of indicators and factor analysis to test the validity of criteria categories have been performed. These results will be used to further refine the instrument.

Results—Factor analysis of the adequacy criteria revealed two prominent factors, quality/control and availability/cost. Item reduction analyses are currently underway.

[269] Arrangements for Receiving Personal Assistance Services

Margaret A. Nosek, PhD; Carol G. Potter, RhD

Independent Living Research Utilization; Department of Physical Medicine and Rehabilitation, Baylor College of Medicine, Houston, TX 77030

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—This study is designed to identify the most common arrangements for receiving personal assistance services; to evaluate quality, control, availability, and cost in four different models of personal assistance programs; and to assess the satisfaction levels of persons with severe physical disabilities who obtain personal assistance through these program models. Relationships among living arrangement, who provides assistance, employment status, and productivity will be assessed.

Recommendations will be made for making formal personal assistance more acceptable, affordable, and available to persons who rely on family assistance (79% of people with disability-related functional limitations), but who could be more productive with additional hired assistance.

Progress/Methodology—The Baylor College of Medicine Research and Training Center on Spinal Cord Injury and

Independent Living Research Utilization (ILRU) have used a registry of 655 persons with spinal cord injury (SCI database) to assess relationships between living arrangement and provision of personal assistance by family, nonfamily, or a combination of both. This now comprises the control group for all subsequent studies of quality, control, availability, and cost of personal assistance services.

Productivity will be assessed by using SCI data that correspond to five components of DeJong's Productivity Scale—work status, educational status, activities outside the home, activities inside the home, and homemaking activities. The resulting productivity score will be analyzed with living arrangement and who provides assistance in a two-way analysis of variance (ANOVA).

To assess relationships between satisfaction with personal assistance and age, duration of disability, living arrangement, income source, productivity, marital status, educational attainment, number of hours of assistance used, and who provides assistance, the above results will be combined with data from telephone interviews of 75 subjects from the SCI database who use more than one hour of assistance daily. These subjects have been selected using stratified random sampling procedures and are currently being interviewed. Twenty-five of the sample use family assistance only, 25 nonfamily only, and 25 a combination. Interviewers are trained consultants from the Houston community who use personal assistance themselves. The interview content consists of demographic information and the Personal Assistance Satisfaction Index.

Relationships between control and satisfaction are being evaluated in four different models of personal assistance delivery: 1) state provision; 2) independent living center provision; 3) home health care agency provision; and, 4) consumer co-op provision. The Personal Assistance Satisfaction Index was mailed to 87 consumers who obtain personal assistance through these programs, and data were analyzed using one-way ANOVA, and the Tukey multiple comparison test.

Preliminary Results—The preliminary study of 655 persons with spinal cord injuries revealed that of the 286 who used personal assistance, 77% lived with relatives. Of those, family provided assistance to 61%, nonfamily assisted 17%, and a combination of family and nonfamily assisted 22%. Of the 10% living with nonfamily, most (70%) received assistance from nonfamily, and of the 13% living alone, nearly everyone received assistance only from nonfamily. Disregarding living arrangement, 50% were assisted by family only, 31% were assisted only by nonfamily, and a combination assisted 19%. The reasons for the unexpectedly higher rate of paid assistance usage will be explored in subsequent studies comparing differences between persons with spinal cord injury and those with other disabilities. One possible explanation is that persons with spinal cord injury may be more likely than persons with other types of disabilities to have access to private sources of funds, such as insurance settlements, and to have had formal rehabilitation that included training in managing assistance needs.

Preliminary results from the survey of use of four personal assistance models indicate that satisfaction levels were significantly higher ($p < 0.05$) for the 25 consumers who obtained services through a progressive home health care agency. This model enabled the greatest flexibility in consumer control: consumers in this highly satisfied group had the option of deciding the extent of the agency's involvement in arranging personal assistance services. Satisfaction levels with the home health care agency were significantly higher than satisfaction with the state provider and the consumer co-op models, but only slightly higher (nonsignificant) than the independent living center.

Recent Publications Resulting from This Research

Personal Assistance Services: A Review of Literature and Analysis of Policy Implications. Nosek MA, *J Disabil Policy Stud* (in press).

[270] Effect of Personal Assistance Services on the Long-Term Health of a Rehabilitation Hospital Population: Perceptions of Rehabilitation Professionals

Margaret A. Nosek, PhD; Carol G. Potter, PhD

Independent Living Research Utilization; Department of Physical Medicine and Rehabilitation, Baylor College of Medicine, Houston, TX 77030

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—This study is designed to test the hypothesis that personal assistance with activities of daily living

significantly affects the ability of persons with severe physical disabilities to maintain good physical health.

Five research topics will be specifically addressed: 1) in the rehabilitation hospital population, the frequency of health problems and preventable complications of disability that can be attributed largely to inadequate personal assistance services will be determined; 2) any differences will be observed in the health status of persons who use personal assistance from family only, paid employees only, or a combination of family and paid employees; 3) services that rehabilitation facilities offer to assist patients in obtaining and managing personal assistance will be identified and evaluated; 4) common complaints will be described about problems in obtaining and managing personal assistance that rehabilitation professionals often hear from persons with disabilities; and, 5) recommendations from rehabilitation professionals will be solicited about what changes are needed in personal assistance services and policies.

Progress/Methodology—A sample of 100 subjects have been selected from the membership of the American

Congress on Rehabilitation Medicine (ACRM) and are currently being interviewed by phone. Interviewees consist of 2 physicians, 2 nurses, 2 social workers, 2 physical therapists, and 2 occupational therapists from each of 10 medical rehabilitation centers. Data will be analyzed using techniques of qualitative investigation. Comments will be categorized and coded for frequency analysis. Simple bivariate procedures may be used to determine relationships among certain types of responses and characteristics of the subjects.

Preliminary Results—Preliminary results from a population with spinal cord injury indicate that a significant portion of persons who use personal assistance services have an abnormally high rate of hospitalization and use of emergency medical services. The portion of variance accounted for by the adequacy of personal assistance services received is yet to be determined.

[271] Occupational Stress Among Executive Directors of Centers for Independent Living

Carol G. Potter, RhD

Independent Living Research Utilization; Department of Physical Medicine and Rehabilitation, Baylor College of Medicine, Houston, TX 77030

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—This first phase of this study is designed to investigate sources of occupational stress, techniques and resources for coping, and strain that results when work demands exceed the coping resources of executive directors of independent living centers (ILCs). In the second phase, these aspects of occupational stress will be investigated in the middle management staff of state rehabilitation agencies and compared with the results from executive directors of ILCs.

Progress—The *Occupational Stress Inventory* (OSI) developed by Osipow and Spokane—consisting of Occupational Roles, Personal Strain, and Personal Resources questionnaires—was mailed to the executive directors of 316 independent living programs listed in the *Directory of Independent Living Centers and Programs* maintained by the ILRU Research and Training Center on Independent Living in Houston, TX. A total of 141 usable questionnaires were returned for a response rate of 45%. Data analysis was completed and a dissertation of the results

was presented in January 1990 at Southern Illinois University at Carbondale.

By using a random sampling procedure stratified according to scores on the OSI, 25 of these respondents were chosen and interviewed by telephone to obtain more specific information about occupational stress. Data are currently undergoing analysis.

For the second phase, the OSI was mailed to approximately 400 administrators of four state rehabilitation agencies.

Results—Role overload was strongly related to strain, despite the availability of many resources. Role insufficiency, however, was not strongly related to strain. Executive directors were able to decrease strain through regular participation in recreation and the use of logic and rational problem-solving strategies when faced with specific stressors. The level of strain that executive directors experienced was similar to that experienced by other technical, professional, and managerial workers.

Future Plans/Implications—Possible reasons will be explored for role overload in executive directors and what

specific problem-solving techniques they use to reduce specific stressors.

[272] New Models for the Provision of Personal Assistance Services

Simi Litvak, PhD; Jae Kennedy, MA; Ellen Lieber, MA
World Institute on Disability, Oakland, CA 94606

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—Various social forces, including the growth of the independent living movement, increasing numbers of older people, increasing numbers of working women, advances in lifesaving technology, and deinstitutionalization have combined to put the issue of home/community-delivered personal assistance services (PAS) on the U.S. public policy agenda. The inadequacy and inequity of the system(s) which provide these PAS through public financing recently have begun to be defined and documented. With the increased interest in improving services, policy-makers have debated the size of the need and demand for publicly funded PAS, the potential cost, and best methods for meeting this demand.

The current research objectives are to: 1) identify existing research on PAS, emphasizing data on need, use, cost, and evaluation of services; 2) analyze current systems of providing PAS, including: sources of payment; recruitment, training, and management of assistants; types and levels of service provided; costs of services; program growth, cost of control methods and quality assurance methods; and degree of consumer control; 3) develop strategies for implementing more effective models of PAS, including those aspects which will assure more comprehensive and beneficial services to individuals and greater consumer satisfaction; and, 4) analyze the effect of using PAS on employment, earnings, medical care utilization, and the receipt of cash benefits.

Methodology—The research is being conducted by two centers. The World Institute on Disability (WID) built on its 1985 survey of the universe of PAS programs in the U.S. by conducting a follow-up mail survey of previously interviewed programs as well as new ones. In addition, WID developed case studies on 16 programs through telephone interviews and review of program management documents. These programs are the largest ones funded by the seven different funding sources at three levels of consumer control. The results of these two surveys are now being analyzed to develop models for more effective PAS delivery under the seven current PAS funding schemes.

The Rutgers Bureau of Economic Research has analyzed the Survey of Income and Program Participation, and is conducting a personal interview survey of a national sample of people with spinal cord injuries, to shed light on the users of PAS and the impact that the need for PAS has on their lives. They also examined the Management Information Systems (MIS) of the 16 case study programs which had such systems, and are developing a model MIS for PAS programs.

Preliminary Results—Results of the research are being examined. They will include the following reports from: 1) Rutgers—Model MIS, Estimating the Need for PAS, The Predictors of Need and Demand for PAS; and, 2) WID—Effect of Government Fundings Source on Personal Assistance Programs: Summaries of 1985 and 1989 Surveys, Changes in PAS Programs Between 1984 and 1988; Case Studies on 16 Representative PAS Programs; and, strategies for implementing more effective models of PAS, including those aspects which will assure more comprehensive and beneficial services to individuals and provide greater consumer satisfaction.

Future Plans/Implications—The major outcome of this research will be to provide policymakers and planners on the national and state levels with the quality of information they need to develop a comprehensive and effective PAS system. This research will allow policymakers to project the costs of a more adequate and equitable PAS system based on new cost, demand, and utilization figures. We should gain a better understanding of how funding source mandates, along with state creativity, have shaped the various ways in which services are delivered. As a result, we will be able to better describe mechanisms that policymakers can use to develop systems that better meet the PAS needs of people of all ages with disabilities. Finally, we hope to gain a clearer picture of how PAS consumers pay (or don't pay) assistants, who the assistants are, and the degree of need for public funding of PAS.

Under the auspices of the new Research and Training Center in Independent Living Policy at WID, we will be building upon the WID research to estimate the cost of a national program of PAS for all who need it, based on projections from actual cost of existing programs and the predictions of type of service and hours needed from the National Spinal Cord Injury Survey.

Recent Publications Resulting from This Research

The Need for Personal Assistance. Rutgers University—Bureau of Economic Research and the World Institute on Disability. Berkeley: World Institute on Disability, 1989.

[273] High School Prevocational Intervention Study

David C. Clemmons

Department of Neurological Surgery, University of Washington, Seattle, WA 98195

Sponsor: *National Institute of Neurological Disorders and Stroke, National Institutes of Health*

Purpose—The vocational difficulties of persons with epilepsy include elevated rates of unemployment and historically low rates of movement into competitive employment through state rehabilitation agencies. Much of the current literature suggests that job development strategies, and not traditional skills-training programs, are most effective in assisting brain-impaired persons to secure competitive jobs. Initiating vocational habilitation work at the high school level is believed to be desirable because: 1) individuals with early onset of epilepsy are more likely to exhibit deficits in neuropsychological, intellectual, and social status than are individuals with postadolescent onset; 2) chronic unemployment as a lifestyle may occur early in this population; and, 3) there may be locus of control, or “learned helplessness” factors present which are more amenable to early intervention.

A prevocational intervention is proposed which is designed to assist epilepsy-impaired high school seniors to enter competitive employment at an early time. It is

hypothesized that the treatment group, relative to placebo and no-treatment controls, will demonstrate: 1) a higher rate of entry into competitive employment; and, 2) a reduced rate of dependence on public subsidy.

Methodology—The treatment is presented in a group format, designed after successful group formats currently used in this center for adult outpatients with epilepsy. Pilot work is presented which suggests the feasibility of using neuropsychological testing results obtained from high school age epileptics as an index of later vocational status. Pilot work also shows an early reliance on public subsidy for epileptics who were subjects in a post-high school vocational status study. Hypothesis testing will proceed by means of *t*-tests, rank correlation coefficients, and distribution-free analyses of variance, and will be adjusted for multiple comparisons. Multiple rank regression methods will be used as an aid in identifying types of individuals who may be expected to benefit from extended or specialized services.

[274] Rehabilitation Engineering Center

William A. Hyman; Gerald E. Miller

Texas A&M University, College Station, TX 77843

Sponsor: *National Science Foundation; National Institute on Disability and Rehabilitation Research; Texas Department of Mental Health and Mental Retardation*

Purpose—This program provides rehabilitation engineering consultation at state Mental Health and Mental Retardation facilities, schools, and other sites utilizing bioengineering faculty, bioengineering students, and special education students. The program provides for design and modification projects which benefit

individual clients or are used within the facility for client treatment or education. Technology workshops are also provided. In addition to direct services, the program is also intended to enhance the rehabilitation technology capabilities of present and future practitioners.

Progress—This is an ongoing program. Initial efforts consist of meetings at each facility to acquaint the staff with the program and the types of projects which would be consistent with available resources. This is followed by frequent meetings to identify and implement projects. A wide array of electronic and mechanical devices have been designed and delivered under this program. In addition, design and electronics workshops have been conducted to enhance the technical skills of on-site personnel.

Results—The direct result of this work is the delivery of new or modified adaptive equipment directly into the rehabilitation and special education settings. Communication devices for nonverbal and motor-limited clients have been developed which allow for simple selection from a limited menu using a variety of input devices. Additional projects included several types of interfaces between clients and environmental devices, and prevocational training devices which provide a reward feedback for completed tasks. Sheltered workshop task design problems were addressed to improve workers' efficiency, and to bring new contracts to the workshop. Music therapy for the child with disabilities has been enhanced through the design of a joystick-controlled musical keyboard. Additional projects in the school setting included aids for teaching mathematics and writing, modifications of self-feeding aids, and the provision of portable equipment for the district's occupational therapist. A micturition alarm was provided for adult residential clients to enhance attendant care. A large-switch television remote control was also developed for a residential setting. Several postural feedback systems were provided, including one using a zero-force shadow switch.

A variety of innovative physical therapy and occupational therapy equipment, including an adjustable height platform and ramp for wheelchair training, and a thumb-extension system with capacity to operate external

devices has also been designed. These devices provide extensive visual and auditory feedback to encourage the young user. Voice/sound-controlled systems for speech therapy have also been developed to enhance vocalization training in children.

Future Plans/Implications—Experience with this program has demonstrated that there is an ongoing need for engineering design input for a variety of client problems at these facilities. The service model has advantages in that continuous engineering services could not be effectively utilized by these facilities at this time. Moreover, this program includes an array of expertise and experience and the resources of the University for fabricating projects.

Future plans include expanding the program to cover more state and school facilities. Technology training for therapists and teachers will also be further developed. For the engineering student, this program provides an opportunity to solve real-world problems, obtain exposure to rehabilitation engineering, and gain an understanding of individuals with handicaps and their needs. The special education student receives experience in applied technology and the model of using engineering students as a low cost design resource.

Recent Publications Resulting from This Research

Engineering Student Design Projects in Physical, Occupational and Speech Therapy. Hyman WA, Miller GE, in Proceedings of the 12th Annual RESNA Conference, New Orleans, 375-376, 1989.
Texas A&M Rehabilitation Engineering Projects. Hyman WA, Miller GE, in Engineering Senior Design Projects to Aid the Disabled. Washington, DC: National Science Foundation, 1989.
Undergraduate Bioengineering Student Design Projects Applied to Real World Problems for the Handicapped. Miller GE, Hyman WA, Int J Appl Eng Educ 5(4):451-456, 1989.
Applications of Force Sensitive Resistors. Hyman WA, Miller GE, in Proceedings of the 13th Annual RESNA Conference, 201-202, Washington, DC, 1990.

[275] A Computerized Information Network Supporting the Choice of Technical Aids

R. Andrich; R. Cappellari; A. Santagostini; M. Lodola; C. Levi; M. Ferrario; A. Pedotti
Servizio Informazioni e Valutazione Ausili, Milano 20148 Italy

Sponsor: *The Region of Lombardy; The Region of Campania; The National Research Council*

Purpose—The goal of this project was to set up a computerized data bank of technical aids and a Technical Aids Counseling Centers network.

Methodology—The first version of the data bank was developed by SIVA on a mainframe (DEC VAX 11/750) and became operational in 1982. Remote access was

available through a modem and telephone line. In 1988, demand for accessing the system increased rapidly among the local health authorities, regional governments, and associations of disabled persons. The data bank was completely rewritten for implementation onto personal computers. The current version requires a MS/DOS-compatible PC with 640K bytes RAM and at least 15M bytes hard disk. Files are organized using DBIII+ format and software has been written by SIVA in Clipper language. The software interface is user-friendly and specially developed for rehabilitation professionals. Extensive user-friendly evaluation has been carried out with over 100 rehabilitation professionals throughout Italy. Distribution of the data bank outside SIVA was organized through quarterly mailing of floppy disks. Every update is a new version of the whole package (data and software) which supersedes the old one. By using data-compression utilities and specific software developed by SIVA, it is possible to store the whole package onto a single 1.44 floppy disk and rebuild the operational version on site. The data bank is always accompanied by a specific training program for the professionals at the local centers

who are concerned with a global approach to counseling on the choice of technical aids.

Results—The data bank currently contains information (continuously updated by a team of experts) on approximately 4,000 technical aids, 5,000 organizations (commercial and noncommercial), legislation concerning the provision of technical aids, selected literature, and criteria for choosing technical aids. A record of the counseling services given to the clients can be kept through a standardized form that is also used as a basis for statistics and follow-up. Fifty-two rehabilitation centers throughout Italy are now accessing the system.

Future Plans—An extension of the information network is foreseen in order to provide qualified information to all disabled Italian persons through the rehabilitation centers.

Recent Publications Resulting from This Research

The Italian Computerised System Supporting a Network of Technical Aids Counselling Centres. Andrich R, in Proceedings of ECART 90, Maastricht, 1990.

[276] Creation of a Regional Network of Technical Aids Information Centers in Lombardy, Italy

R. Andrich; I. Johnson; A. Santagostini; A. Pedotti
Servizio Informazioni e Valutazione Ausili, Milano 20148 Italy

Sponsor: *The Region of Lombardy*

Purpose—The purpose of this project was to create a network of technical aids information centers throughout the regional territory, with SIVA taking the lead at two levels: information management (i.e., collection, processing, distribution), and specialized counseling.

Methodology—There are 80 local health units (USSL) responsible for the health care and social services in Lombardy. Fourteen USSLs were selected to represent the region for the experimental period between 1988 and 1990. In order to create a multidisciplinary team for each information center, the USSLs were asked to identify three categories of professionals suitable for this purpose: a person responsible for the project (frequently chosen was a medical doctor specializing in rehabilitation and responsible for prescribing technical aids), at least two rehabilitation therapists already part of the rehabilitation staff and willing to be directly involved with counseling

in the information center, and an administrative officer charged with prescription control.

Courses were organized to prepare the professionals for their new tasks: 1) technical aids (1 week); 2) information retrieval and documentation handling, including practical experience of the SIVA computerized data bank (3 days); and, 3) counseling (1 week). All information centers were planned to be accessible for disabled persons, and designed to facilitate communication among the staff. The data bank was implemented onto a PC Olivetti M240 and distributed to all 14 centers. During the project, the data bank was updated quarterly.

Results—The Technical Aids Information Centers are now working regularly in 11 of the 14 USSLs chosen for this project. The centers are open to the public 2 or 3 days a week (for a total of at least 10 hours a week).

Future Plans—The Region of Lombardy is considering the possibility of extending the experiment to the other

USSLs to include the activities of the local information centers into the general routine of the rehabilitation units.

[277] Independent Living at Home for Severely Disabled Persons: An Experimental Project

M. Ferrario; R. Ronchi; M. Lodola; A. Rivarola, MD; R. Cardini, MD; A. Pedotti
Servizio Informazioni e Valutazione Ausili, Milano 20148 Italy

Sponsor: *The Region of Lombardy, National Research Council*

Purpose—The purpose of this study is to verify to what extent severely disabled persons can achieve or maintain a degree of personal autonomy when performing the activities of daily living with the support of technical aids.

Methodology—The project sample consisted of 12 quadriplegics with a wide range of disabilities, but with no severe cognitive limitations. The pathologies concerned were cerebral palsy, multiple sclerosis, and trauma.

Selection of the sample group for this 3-year project was based on various parameters—ability to modify living quarters, implementation of technical aids, and the execution of the necessary modifications.

Of the 72 families interviewed, 12 filled the requirements for participation in the study. The following were distributed to the clients and their families: 76 communication aids (including hardware, software, switches, etc.); 42 mobility aids (including manual and powered

wheelchairs); 18 pieces of stair-climbing equipment; 12 hoists; 12 beds; 10 bathroom modifications; and 7 anti-decubitus aids. The majority (more than 80%) of these technical aids needed specific personalization.

Results—Twelve families were involved in the project and can now be considered more independent in their daily lives. Technical aids and proper training dramatically reduced the need for personal assistance for the most frequently performed tasks of daily living.

Future Plans—An extension of this project is deemed necessary in order to validate the findings.

Recent Publications Resulting from This Research

Experimentation for Counseling, Personalization, and Teaching
How to Use Aids and Technical Devices for a Personal and/or
Housing Autonomy for Severe Quadriplegic People. Ferrario M.
in Proceedings of ECART 90, Maastricht, 1990.

[278] SEDL/Regional Rehabilitation Exchange

John D. Westbrook, PhD; Jack Lumbley; Dale Pfefferkorn
Regional Rehabilitation Exchange, Austin, TX 78701

Sponsor: *National Institute on Disability and Rehabilitation Research; Southwest Educational Development Laboratory*

Purpose—The Southwest Educational Development Laboratory/Regional Rehabilitation Exchange (SEDL/RRX) identifies, validates, and disseminates effective rehabilitation practices focusing on critical needs areas in Federal Region VI: Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.

The goals of the Regional Rehabilitation Exchange are twofold. The first goal is to promote the use of validated exemplary programs, products, and practices resulting from rehabilitation research, training, and service delivery in the areas of Independent Living Services, Job Placement Services, Supported Employment Services,

and Transitional Services. Using a detailed, uniform evaluation procedure that includes peer review, the RRX validates rehabilitation and independent living programs that are especially effective and recognizes them formally as exemplars. These exemplary program models generally demonstrate a high success rate, surpass established performance standards, show significant and stable results, are cost-effective, and include adaptable or transportable components. Six newly identified exemplary programs in 1989 and ten in 1990 were identified and validated throughout the four core areas to join previously identified programs as technical assistance resources.

The second goal is to provide technical assistance for program improvement and/or new program initiation purposes. In some instances, the RRX can broker and provide in-depth technical assistance to agencies or organizations. This is done by matching the technical assistance needs of the organization/agency/school with exemplary program components and service providers who have demonstrated expertise in those areas: RRX funding will provide the consultation fee and travel expenses of the consultant. Evaluations of technical assistance provided to organizations take place several times over the year following the activity.

Results—Greater results have been shown from the recipients receiving the technical assistance than the exemplary programs, due to the fact that the recipients did not have to develop a proven model through trial and error, thereby saving staff time and resources.

Results of this past year have included formal agreements with state agencies in each of the five states to

provide for the cooperation of the various state agencies and the RRX in the planning and implementation of services in the core areas listed above in order to obtain/maintain supported/transitional employment for individuals with severe disabilities within the state. Individual organizational agreements also took place for the purpose of program initiation or enhancement that lead to greater programmatic outcomes. Several special focus workshops also took place in the areas of "Successful Job Placement Services for Persons with Traumatic Head Injury," and "Exemplary School-to-Work Transition Programs."

Future Plans—The RRX is beginning its third year of a three-year NIDRR grant. Project goals for the third year are to continue to identify exemplary programs in RSA Region VI, as well as to provide technical assistance to service providers for people with disabilities in the areas of Independent Living Services, Job Placement Services, Supported Employment Services, and Transitional Services.

[279] Effect of Personal Assistance Services on Productivity and Daily Living Among Japanese with Severe Physical Disabilities

Margaret A. Nosek, PhD

Independent Living Research Utilization at The Institute for Rehabilitation and Research; Department of Physical Medicine and Rehabilitation, Baylor College of Medicine, Houston, TX 77030

Sponsor: *World Rehabilitation Fund*

Purpose—The purpose of this study was to pilot-test a methodology for assessing arrangements through which persons with disabilities obtain personal assistance to compensate for their functional limitations, levels of satisfaction with these services, and the effect that personal assistance services have on their productivity and daily living.

Progress—Thirty subjects were recruited from the Tokyo and Kansai areas with the assistance of the Human Care Association—an independent living center in Tokyo—and organizers of the Ninth Annual Conference of Wheelchair Users, held September 1989, in Hyogo, Japan. Persons who were active in disability-related consumer organizations such as independent living centers or advocacy organizations were recruited the most intensively. Each individual completed a written questionnaire consisting of demographic data: the Personal Assistance Satisfaction Index (PASI), and the DeJong Productivity Scale. Of this sample, 15 were also interviewed in person.

Results—The most common disability represented was cerebral palsy, followed by quadriplegia from spinal cord injury, then muscular dystrophy. Of the majority who lived with family (73%), only family provided assistance in 40%, only nonfamily did in 20%, and a combination assisted in 12%. The second most common arrangement was living alone (27%), in which nonfamily members, usually paid workers, provided assistance (24%). No one lived with nonfamily. The average amount of personal assistance used was 11 to 20 hours per week. Regarding payment for services, 44% received assistance free, 16% used their own funds, 12% used government-paid assistance only, 12% used a combination of free and government-paid assistance, and 16% used their own funds combined with free assistance. More than three-quarters of the subjects (78%) stated that they were dissatisfied with both the availability and the cost of personal assistance. There was no significant difference between the satisfaction scores of residents of Tokyo, where considerable city funding is available for personal

assistance services, and those from other parts of Japan, where funding is scarce. Those who lived alone but used nonfamily assistants had the highest level of satisfaction, while those who lived with family but had nonfamily assistants had the highest level of productivity. Individuals who were among the most satisfied were more likely to be married and to have nonfamily, paid assistants. Individuals who were among the most productive also tended to be married, older, and less educated.

Anecdotal data indicated a strong desire for more control over arranging personal assistance, greater availability of persons to serve as assistants, and more funds to pay them. Of the 15 subjects interviewed in person, 11 said they preferred family or hired persons as assistants. Those favoring family felt freer asking for the assistance needed, and the quality of assistance was better. Those who preferred hired personal assistants cited control over the selection of the assistant and the scheduling of assistance. Subjects who received assistance from the Home Helper system unanimously expressed dissatisfaction with their inability to choose the assistant and the patronizing attitude of the assistant. Eight subjects commented that they lacked enough personal assistance to achieve the level of productivity they desired. Reluctant to ask for the extent of assistance actually needed from family, many felt that they must sacrifice their productive aspirations to minimize the burden on their family.

Only a small portion of Japanese citizens with disabilities are competitively employed, which reflects not only a lack of appropriate assistance services, but also their exclusion from the mainstream educational system, as well as the negative attitudes of employers toward people with disabilities. Separate educational facilities fail to equip them with the social and educational skills necessary to compete in the real working world. In addition, architectural and transportation barriers limit their mobility in the environment. Consequently, the primary activities reported were volunteer work or participation in sheltered workshops.

Implications—The results of this study strongly suggest the need for national policies on personal assistance services in both Japan and the United States, as well as a commitment to establish national programs that offer broad personal assistance services at a reasonable cost and with a range of options for consumer control of the services. Only then can persons with physical disabilities realize their full potential for productivity in the community.

Recent Publications Resulting from This Research

Personal Assistance Services in Japan: Effect on Productivity and Daily Living Among Japanese with Severe Physical Disabilities. Nosek MA. New York: World Rehabilitation Fund, Inc., 1990.

[280] West German Building Standards to be Transferred as a New General Barrier-Free Building Code

Dieter P. Philippen, MSc, BSc

Institute T.L.P.e.V., Rehabilitation Research and Development, D-5580 Traben-Trarbach, Germany

Sponsor: None listed

Purpose—New building standards were needed to establish barrier-free environments for disabled and elderly persons.

Progress—The West German building code DIN 18025 Part 2 (applicable in both parts of Germany) is the most advanced building standard for a general concept of a barrier-free environment and is, with great political support, on its way into legislation as an adaptation of general building codes.

It is an example of a joint European effort and is a concept to solve housing requirement problems of the disabled and elderly in environmental and urban developments.

This new set of regulations decreases the need for special housing and concentrates on integration by designing major multiples for a given and future situation of population mixture in age and disability.

Results—During the 2-year development of the new standards, a comparison was conducted to evaluate the differences in codes and standards of other European countries. It was concluded that a joint European concept, integrating adaptable housing features, is quite feasible.

A selection of various planning concepts applying the new codes (which define functional spacing with each object of use, instead of defining room sizes), is available

upon request for various selected home sizes and for single problem areas (e.g., bathrooms or kitchens). There is a charge for postage and handling.

Future Plans—Several experimental building projects have been initiated with the new concept, in order to have a comparable base of building cost between the traditional and the new type of barrier-free construction, including

vertical access to all building levels. A report and commentary containing these research results will be published with an addendum concerning all buildings accessible to the public, applying the same basic concepts, including that of barrier-free work- and job-sites for all.

The various reports and detailed publications will be available in Spring of 1991.

[281] Development of a Dynamic Interactional Rehabilitation Data System

Dieter P. Philippen, MSc, BSc; Holger Brittinger

Institute T.L.P.e.V., Rehabilitation Research and Development, D-5580 Traben-Trarbach, Germany;
Data-Technology, 5562 Zell/Mosel, Germany

Sponsor: *None listed*

Purpose—The dual purpose of this project is to develop: 1) a factual international technology transfer system (interconnected within a service center network), offering access to an interactional data system for all rehabilitation research and development supplying information for local counseling; and, 2) a basic library for a first full university master study in rehabilitation engineering, to be launched in Aachen, Germany.

Progress/Methodology—We have completed development of software for a rehabilitation databank system which links data to the specific problem area, in direct relation to a given anatomic or disability situation, integrated with an additional link to a given area of application or use, enabling specification on research needs following feedback of performance information.

These links and interconnections (a capacity of 40 interconnections in depth and endless in length), enable direct comparative reference to a given matrix of anthropometric or ergonomic values. Any item or additional interconnection or link can be added during data entering without further programming. The basics of the data collection software offer extensions into macro structures for integrated links to other sources of information. There is a built-in provision for multiple addresses, and space for additional internal comments on each set of information. If the comments contain appropriate key words or

graphics (the system will eventually combine with a CAD surface and software), it will enable architectural and barrier-free counseling on all types of housing and environmental developments.

Future Plans—The software will provide additional integrated possibilities to include drawings, graphics, or scan-in photos for each set of data, and is designed to run on a 386 AT with at least 2 MB-RAM. It can communicate with central computer systems, and network with any type of data transfer possible with any type of data communication system. This system was developed especially for rehabilitation, and will provide all of the requirements for regular data collection (including filing and use of do-it-yourself solutions), for scientific research data, and medical or therapeutic information (e.g., architectural planning details). The system is in use at the Institute T.L.P.e.V. and will, after final development (scheduled for the summer of 1991), be offering services on three levels for: 1) individual disabled persons; 2) experts, therapeutic professionals, etc.; and, 3) scientific research.

We plan to open up the system to international cooperation and joint ventures and to interconnect with projects (e.g., research methods and application possibilities of traditional medicine and therapy from the People's Republic of China) to improve western rehabilitation therapy.

[282] Research of Therapy and Traditional Medicine Application in Rehabilitation in the People's Republic of China

Dieter P. Philippen, MSc, BSc; Sheng-Wen Xu, MD; Kerong Dai

Institute T.L.P.e.V., Rehabilitation Research and Development, D-5580 Traben-Trarbach, Germany; Shanghai Second Medical University, Shanghai; Huan-Shan Medical Centre, Shanghai; Ninth People's Medical University, Shanghai; Shanghai Jai-Tong University, Shanghai; Shanghai Institute of Physical Education, Shanghai; Shanghai Qi-Gong Research Institute, Shanghai; Zhejiang Medical University, Shanghai; Shanghai Academy of Traditional Chinese Medicine, Shanghai, People's Republic of China

Sponsor: *None listed*

Purpose—Four years of preparation and investigation of the procedures and possibilities of rehabilitation in the People's Republic of China have clearly indicated the need to make the knowledge and procedures of a combination of Chinese traditional medicine with Western medicine (which mainly serves as ambulatory therapy), available to Western rehabilitation centers.

Progress—An agreement of cooperation has been signed between the Institute T.L.P.e.V. and seven of the leading Shanghai universities and research centers for rehabilitation and traditional medical application and adaptive Chinese technology. Preparations are being made for installation of the first information, training, and treatment center in one of the European Community countries, which will be staffed with rotating Chinese specialists from various fields.

Chinese rehabilitation techniques are not directly comparable to the Western concept, but the combined application of Western and traditional methods in China offers a totally new and fascinating chance for a major improvement of Western rehabilitation. We shall inves-

tigate to what extent methods are transferable (including knowledge and application of traditional herbal medication from China), during an exchange of specialists from both sides. Three of the leading German rehabilitation centers are preparing to coordinate and take part in this 5-year project, for which a request for German federal research funding is being submitted.

Chinese researchers have developed some low-cost memory-shape alloys for orthopaedic applications and low-cost endoprosthetic implants and artificial joints, and have also combined functional electrical stimulation with traditional acupuncture. This technique uses lasers plus acupuncture needles, instead of wholly relying upon needles. These methods are some of the technology presently being investigated in detail for development in China.

Future Plans—We intend to open this project for participation by scientific or rehabilitation centers of other countries, and to organize a joint venture in research evaluation which will consider the interdisciplinary individual interests of such countries.

[283] Development of Methods for Egress of the Disabled and Elderly from Private or Public Buildings

Dieter P. Philippen, MSc, BSc; T.J. Shields

Institute T.L.P.e.V., Rehabilitation Research and Development, D-5580 Traben Trarbach, Germany; Department of Building, Fire Research Centre, University of Ulster at Jordanstown, Newtownabbey, County Antrim BT37 OQB, UK

Sponsor: *None listed*

Purpose—This is both a project report and an urgent call for joint action on a matter of mutual concern for all countries, namely, the question of emergency egress for disabled and elderly from buildings. The need to provide not only "access for all," but to solve the problem of egress for disabled and elderly people from any type of building in case of emergency has been neglected.

Sufficient provision of egress has been given far less attention than has equal access.

Practical solutions or detailed information for the rescue of disabled or elderly people from burning buildings are not available. This applies whether those buildings are private homes, apartment buildings, or public-accessible buildings of any kind. Most building

codes make no special provisions for the disabled or elderly, and all safety codes have been formulated based on able-bodied persons.

Progress—A preliminary investigation of building codes and standards of 32 countries has shown that no special consideration is given to handling the evacuation of disabled or elderly people in case of fire or other emergencies, except for advice for special attendant care. The Institute T.L.P.e.V. has joined forces with the University of Ulster to launch a research and development project

to find solutions and to develop basic requirements to be included in all building codes and technical safety standards.

Implications—This is an international matter of mutual concern and responsibility for all countries. It is presented as an offer for a joint venture on research. Through an understanding of technology transfer, we hope to exchange information, and combine international knowledge and abilities to solve this problem of mutual interest and importance.